EXAMINING THE READINESS OF ARTIFICIAL INTELLIGENCE IN CONSTRUCTION LOGISTICS

LAU SIN YING

A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying

Lee Kong Chian Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

April 2021

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature : 

Name : Lau Sin Ying

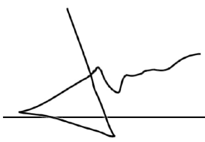
ID No. : 1602676

Date : 6th May 2021

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"EXAMINING THE READINESS OF ARTIFICIAL INTELLIGENCE IN CONSTRUCTION LOGISTICS"** was prepared by **LAU SIN YING** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying at Universiti Tunku Abdul Rahman.

Approved by,

Signature : 

Supervisor : Sr Li Zi Qian

Date : 7 May 2021

Signature :

Co-Supervisor :

Date :

ACKNOWLEDGEMENTS

I would like to thank everyone who had contributed to the successful completion of this project. I would like to express my gratitude to my research supervisor, Sr. Li Zi Qian for his invaluable advice, guidance and his enormous patience throughout the development of the research.

In addition, I would also like to express my gratitude to my loving parents and friends who had helped and given me encouragement throughout the process of this research.

ABSTRACT

The world is constantly changing especially in construction industry, which is always competitive, complex and challenging. Due to its uncertain and dynamically changing environment, logistics has become a core pillar in delivering a construction project successfully by having the right product with right price, right quality and right quantity at the right place on the right time to the right customer (8R). Since these requirements are getting more and more difficult fulfilled, Logistics 4.0 has triggered changes and improvements in current traditional logistics practices by integration of new intelligent technologies. Artificial intelligence (AI) is one of the driving force of Logistics 4.0 and its continuing development will transform construction logistics with unprecedented velocity in the near future. Thus, are Malaysian construction practitioners ready to adopt AI in their logistics practices? This research intends to examine the readiness of local industrial players towards the adoption of AI in construction logistics. The objectives are to uncover the problems faced in current construction logistics practices, to identify the existing practice of AI in construction logistics and lastly to study the readiness of industrial players to adopt AI in the practices in construction logistics. The literatures pertain to the benefits of Logistics 4.0, the problems in current construction logistics practices and the applications of AI in construction logistics are reviewed. Sampling size was determined by Central Limit Theorem to ensure the reasonably sufficient size of samples. Quantitative research approach was used for collecting data. A total of 154 sets of questionnaires are collected from targeted respondents to assess construction industry players' problems faced in current logistics practices as well as their awareness, existing practices of AI and barriers in adopting AI. In overall, there is relatively high awareness among players and can be concluded that they are ready now for AI adoptions. However, due to some barriers, AI remains its infancy in local construction organisations when most players are planning to adopt AI in the near future instead of using now. Malaysian construction players are expected to be beneficial by having higher awareness and readiness in exploiting and embracing these new emerging intelligent technologies. The future researcher may define more specific scope by focusing on the readiness of specific AI innovation in construction logistics.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS / ABBREVIATIONS

AI	Artificial Intelligence
ML	Machine Learning
DL	Deep Learning
BC	Black Carbon
CPS	Cyber-physical system
IoT	Internet of Things
IoT & S	Internet of Things and Service
RFID	Radio Frequency Identification
RTLS	Real Time Location System
AGV	Automated Guided Vehicles
AV/AVs	Autonomous Vehicles
RPA	Robotic Process Automation
UAV	Unmanned Aerial Vehicles
UGV	Unmanned Ground Vehicles
ROI	Return of Investment

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

This part acts as the introductory chapter for this research. Section 1.2 uncovers the background information of artificial intelligence (AI) adoption in Malaysian construction industry and then follow by Section 1.3 which reveals the previous studies in this area. Section 1.4 discusses the research aim and research objectives. The research methodology used is introduced in Section 1.5 when Section 1.6 defines the scope and limitation of this research. Lastly, Section 1.7 provides a briefly outline for the chapter of entire research.

1.2 Background of Study

In the past decades, AI has become one of the biggest success stories related to technology. The AI technology influences across various sectors from virtual doctors to driverless cars as well as transforms the society, individual and also enterprises in the 21st century (UK's Department for International Trade, 2017).

Price Waterhouse and Coopers & Lybrand (PwC) (2017) estimated that AI will drive global Gross Domestic Product (GDP) 14% higher in 2030. It means additional $15.7 trillion to the global economy. In a similar vein, through the study from International Data Corporation (IDC) Asia Pacific and Microsoft, it stated that productivity of employee in Malaysia is predicted to be improved 60% with AI application. However, those organisations in Malaysia which have embarked on the journey of AI are only 26% of them. In 2021, the competitiveness of these companies with AI innovation is expected to be increased by 2.2 times (Paramasivam, 2019). Thus, a real risk of failing to enjoy these competitive benefits is embedded for those businesses and economies which have yet initiate AI innovation in their organisations

Based on economic report 2020/2021, the Ministry of Finance Malaysia (MoF) stated that the construction industry is expected to rebound the GDP the most by 13.9% in economic recovery of 2021 after pandemic COVID-19. Thus, it is obvious that the construction industry plays a significant role (Zainul and Shankar, 2020). However, the construction industry has a reputation of being traditional and conservative. In the past decades, the possibilities of AI have started to be woke up in construction industry. Construction Industry Development Board (CIDB) (2018) stated that it is no strange for construction industry to accept the disruptions of technology as the synergy between technologies with traditional practices. The new working ways tend to be human-AI collaboration. The applications of AI solutions with machine learning begin emerging in the construction sector (Construction Industry Development Board, 2018). For example, the first robotic bricklayer, Hadrian was invented in 2015 and able to lay about 1,000 bricks per hour (VolvoCE, 2019).

In order to deliver a construction project on time and within budget, construction logistics is one of the most important factor. However, construction logistics is unpredictable with various variables in forecasting, storing and transporting the materials. For example, there are hundreds of multi-ton loaders, excavators, haulers and other heavy equipment involved in construction sites, when one of the construction logistics activity comes into problems, all of these equipment only can sit idle and waiting. This will cause unnecessary construction costs, increase in gas emissions and time waste. Thus, the problems associated in the current construction logistics practices such as productivity and quality decrease, occupational safety have highlighted the importance of AI automation and robotics technologies for traditional construction logistics. It is essential for logistics to embrace these operational complexities and evolve by innovating technology in order to turn complexity into advantages (Businesswire, 2020).

1.3 Problem Statement

There are several studies related to several technologies used in construction industry. For instances, Mahmud, Assan and Islam (2018) studies that the Internet of Things (IoT) potential in construction industry in Malaysia. Other than this, Lanko, et al., (2018) studied the application of radio frequency identification (RFID) combined with blockchain technology in construction materials logistics. Besides, there is also study done by Li, et al., (2016) about the application of real-time locating system (RTLS) in construction industry. However, there is limited research about the adoption of AI is conducted respectively to construction logistics in Malaysia. Malaysian construction industry is still yet to know the application of AI in the logistics practices and the readiness of local construction organisations towards AI adoption. Thus, the followings are the research questions which intend to be answered in this study. Are the local construction industrial players ready to adopt AI in their logistics practices?

1.4 Research Aim and Objectives

The research aim in this study is to examine the readiness of industrial players towards the adoption of AI in construction logistics. The research aim is achieved through the following objectives:

(i) To uncover the problems faced in current construction logistics practices.
(ii) To identify the existing practices of AI in construction logistics
(iii) To study the readiness of industrial players to adopt AI in the practices in construction logistics.

1.5 Research Methodology

As this was a quantitative research, the primary data in this study was collected by using questionnaire. These data collected were analyzed by using normality, reliability test and both descriptive statistics and inferential statistics in order to recognize the relationships among the variables. The research approaches adopted to achieve the objectives of this research was summarized in Table 1.1.

Table 1.1: Summary of Research Approaches

Phase 1		***Phase 2***
Literature Review		*Questionnaire Survey and Data Analysis*
Objective 1: To uncover the problems faced in current construction logistics practices.	**Objective 2:** To identify the existing practice of AI in Construction Logistics.	**Objective 3:** To study the readiness of industrial players to adopt AI in the practices in construction logistics.

1.6 Research Scope and Limitations of the Study

The data are gathered from individuals who have experiences or work related throughout or part of the construction logistics from raw material supplier, manufacturing factory, supply house until construction sites (include boundaries and within site). This research may be limited within the temporal dimension as not covered the latest AI applications in construction logistics. This is because AI is a rapid changing technology that still developing throughout the industry.

1.7 Chapter Outline

This research contains five chapters when Chapter 1 is the introductory part for the entire research. It discusses the background of the adoption of AI in Malaysian industry and also in context of construction industry. This chapter also points out the problem statement, aim and objectives for this research. The research methodology conducted is highlighted and the restraints are briefly introduced as well. Chapter 1 is ended up with the outline of the report.

Next, Chapter 2 critically discussed about the AI and construction logistics. It provides a brief account on the problems faced in current practices of construction logistics and the benefits of Logistics 4.0 in construction logistics. The application of AI in construction logistics discussed includes automated guided vehicles (AGV), unmanned aerial vehicles (UAV) and unmanned ground vehicles (UGV), unmanned tower crane, smart construction lift, autonomous trucks, AI-based drones, AI-powered jobsite cameras, predictive analytics and AI-back office. The challenges faced when implementing AI also be covered in this chapter. The theoretical framework of AI adoption in construction logistics is established at the chapter’s last section in order to demonstrate the relationship among the variables discussed in this research.

Chapter 3 represents the brief account of research and follows by the research method types, data collection approaches, research philosophy and method to analyse data. The research design for this research also is covered. The sample frame, size, method and target respondents for this research also are revealed. Subsequently, the timeline or milestone of this research has outlined.

Chapter 4 presents the data collected from questionnaires. The data collected is analysed by normality test and reliability test. Both descriptive and inferential statistics are adopted in this chapter. The findings are evaluated and compared with literature reviewed in Chapter 2. This chapter also discusses the findings about the top three problems in construction logistics practices, awareness of construction organisations towards the benefits of Logistics 4.0 and AI adoption in construction logistics. The top challenges in adopting AI as well as the current readiness of AI adoption in construction logistics are also discussed in this chapter.

Chapter 5 is the final chapter of this research. The findings are summarised in this chapter by concluding the entire research and the current level of readiness of AI adoption in logistics of Malaysian construction industry. The implications are also discussed in this research. This chapter also reveals the limitations of this research and recommendations for future study to enhance the quality of similar research in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents the reviews of literature which summarize the research about artificial intelligence (AI) and construction logistics. Section 2.2 briefly explains the definition of AI and follows by introducing the structure and types of AI in Section 2.3. Section 2.4 and 2.5 critically discussed the construction logistics and problems in current practices in construction industry. Benefits of Logistics 4.0 in construction industry will be reviewed in Section 2.6. The current implementation of AI in construction logistics and the challenges faced in AI adoption in construction industry are reviewed in Section 2.7 and 2.8. A theoretical framework for AI will be proposed in Section 2.9. Lastly, the summary in Section 2.10 discloses the next chapter.

2.2 Definition of Artificial Intelligence

The term of "Artificial Intelligence (AI)" was coined by John McCarthy in 1956. Due to evolution of technology and research in AI, the definition of AI has varied over a wide range. Sivalingamm (2020); Cui, et al. (2020) defined AI is an umbrella concept used to define a machine imitates human cognition such as pattern recognition, problem-solving and learning, eventually human works are superseded or augmented. Similarly, Rai, et al. (2019) perceived AI is "the ability of a machine to perform cognitive functions that associate with human minds, such as perceiving, reasoning, learning, interacting with the environment, problem solving, decision-making, and even demonstrating creativity". In the same way, Savić (2019) viewed that AI emerged initially as the earliest edition of expert system, however nowadays it is able to behave and analyse lucidly and independently as well as possesses autonomous operation in a manner similar to humans.

Contradictorily, Lorica and Loukides (2016) concluded that it is not only difficult but impossible to define AI because human really lack understanding about human intelligence. Paradoxically, AI developments can help in defining what not human intelligence is, instead of what AI is. In addition, Faggella

(2020) reviewed that it is so difficult to set a definitions for AI because there is not any solid concept available for AI in general. Yudkowsky (2008) also noted that if human draw the conclusion of understanding about AI too early, it will be the biggest risk for AI. However, Eric Jonas who is the assistant professor at the University of Chicago reviewed that “AI is a lie” which means the current reality of AI development is quite premature and far from the expectations for AI as well as create many queries such as whether AI will replace human for completing jobs, the role of AI for human and its ethics (Webb, 2019).

The diverse definitions of AI continue to develop in defining more specific fields or subcategories, each definition is essential in helping researchers to gain the goals and guidelines (Lorica and Loukides, 2016). There are various forms for AI, for example voice assistant which are Siri or Alexa, recommendation systems which are used in Alibaba or Amazon as well as the online platforms for labours such as Uber or MTurk (Alahmad and Robert, 2020). In this final year project, AI is defined as the advanced technology in helping the construction logistics sector to overcome current practices’ greatest issues or challenges which including safety, scheduling and costs (Blanco, et al., 2018).

2.3 Structure and Types of Artificial Intelligence

Typically, there are 4 layers available in an AI system. The topmost layer is AI itself which involve the absorption, storage and process of information for decision-making (Heller, 2019). The user of AI will gain the experiences similar when they interact with human. The Turing Test is a test which attempted to identify whether a computer intelligent is enough with indistinguishable human behaviour and able to convince real human through communications. The successful example in passing the Turing Test is Eugene Goostman who is a fake 13-year-old kid and tricks 33% of the judges believe that he is a real human after having conversations with him (Aamoth, 2014). Figure 2.1 illustrates the 4 layers available in an AI system.

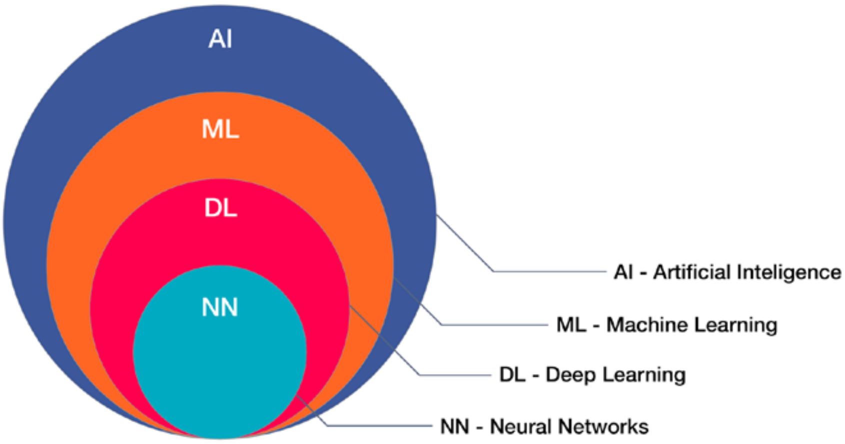


Figure 2.1: A visual representation of four layers in AI system
(Source: Motalebi, 2020)

Secondly, the layer below AI is machine learning (ML) which is the subset of AI as well as a system that can learn by itself (Motalebi, 2020). Most of the advancements and applications in AI nowadays in software, medicine, robotics and business are classified as ML (Hall, et al., 2014). Basically, ML algorithms act as the statistical tools which is fed with vast amount of information, then it starts to analyse and recognize to find the patterns in the existing data given and finally classifying data or making predictions to get a specific result (Ergen, 2019; SSI Schaefer Whitepaper, 2019). ML is used as a classifier to recognize objects, for example in the spam classification, ML algorithms which immersed in zillions number of emails start to learn how to identify certain elements in distinguishing spam from authorized emails, finally it can classify whether the email is either “not spam” or “spam” (SSI Schaefer Whitepaper, 2019). Human kids learn from their parents and school under highly structured system, when growing, adults gain more experience and well adapted to look for their inputs and learn from different aspects around the world. Similar to machine, they need to learn from data (Gesing, et al., 2018).

Typically, ML algorithms use three main techniques in learning which are supervised learning, unsupervised learning and reinforcement learning. Supervised learning is directly under human guidance, the example application is detection of disease. Unsupervised learning is involved in identification of dimensions or clusters in data without extra human guidance such as by observing 10 millions of cat, cat faces able to be recognized by YouTube itself from uploaded video (Gesing, et al., 2018). Moreover, under the reinforcement learning, ML algorithms will achieve its objective by learning with trial-and-error approach and through the observation of surrounding situation itself. For instances, an autonomous car has its objective which is driving safe all the time on road, when it fails in achieving its objective, penalty will be given and it will try for several times until the useful and right decision is made to get an occasional reward (Kiran, et al., 2020).

The third level is deep learning (DL) which possesses the capability of AI to process speech, images and language. The term “deep” indicates the amount of network’s hidden layers. Lastly, the AI system’s bedrock is neural network which involved data processing (Heller, 2019). Typically, DL is done with neural network technology. Neural networks are the greatest effort to imitate both human brain’s structure and function, with the aim to address issues in an identical way to human (SSI Schaefer Whitepaper, 2019). When neural network is fed with new data, the link between each node is set up, reinforced or reduced. The scenario is similarly with neurons connections in human brain, become stronger by repeated experiences. Moreover, each neural network connection is possible to be adjusted or tuned, allocate lesser or greater significance to an attribute to accomplish the output’s quality (Gesing, et al., 2018). Figure 2.2 illustrates the image (input) is broke up by the neuronal network into several partial images. They are then processed by single layer such as corners and edges. For example, the first hidden layer will compare the adjacent pixels’ brightness to detect the edges, then this data is transfer to the second hidden layer to search for corners, eventually pass to third hidden layer to look for the group of edges and corners until able to identify the certain or specific object (output) (SSI Schaefer Whitepaper, 2019).

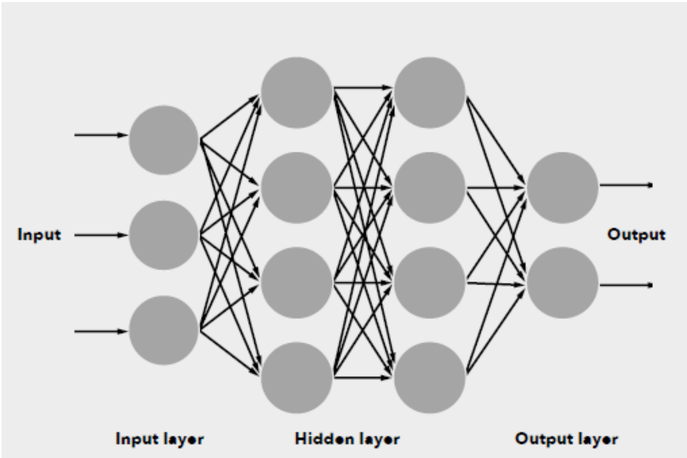


Figure 2.2: Layers of neuronal network
(Source: SSI Schaefer Whitepaper, 2019)

AI is categorised into two types. General or strong AI possess the entire autonomous thought by imitating the human brain when narrow or weak AI is the establishment of smart machines to deal with the complicated problems (Heller, 2019). The general AI systems are as flexible and influential as human intelligence and are not tailored in dealing with a particular task or problem, however the creation of general AI has not been established (Wirth, 2018). Nevertheless, the increasing and growing developments today in the narrow AI's field offer massive opportunities for ultimate invention of general AI. The example of current advanced creation of narrow AI is IBM's Deep Blue and Watsons. Narrow AI such as Apple's Siri and Amazon's Alexa begin to penetrate into human's daily life by making continuous and regular changes (Heller, 2019).

2.4 Construction Logistics

The ultimate objective of all construction projects is to complete the project on cost and on time with the agreed quality. Infrastructures or houses are the end product by construction industry, and they are produced from massive number of materials which are required to be transported to the consumption point or construction site (Lindén and Josephson, 2013; Ekeskär and Rudberg, 2016;

Thunberg, Rudberg and Gustavsson, 2017). It means that the completion time of a construction project rely heavily to the manufacturing and transportation of materials to site (Lindén and Josephson, 2013). Thus, the construction logistics play an essential role in delivering the project successfully.

Construction logistic involves domestic or international transportation of a bulky and large volume of materials or components, thus there are different mode of transportations provided such as rail, road, ship or air (Sisko, 2019). Brown (2013) viewed that construction logistics starts as subcontracting business carried out by labour masters providing bodies in works such as moving materials and also cleaning up. In an identical vein, Janné (2018) described construction logistics is the correct materials are dealt and supplied to the right customers and construction sites in order to fulfil the requirements of customers. For example, the logistics for in-situ construction project are involved transportation of materials to construction site directly after contractor has placed the order; but for precast or modular construction project, the materials are initially dispatched to the manufacturing facility in order to transform the raw materials into modular components (Li, et al., 2014).

On the other hand, the construction logistics can also be explained as a transportation operation that is costly, complex and required highly social responsibilities because it is bounded with the life cycle of product and engaged in organisations network. Some instances of construction logistics activities are planning, on-site and off-site warehousing, supplying and maintaining unloading and loading zones, on-site and off-site materials handling (Lindén and Josephson, 2013; Ekeskär and Rudberg, 2016; Transport for London, 2017; Sundquist, et al., 2018). Lundesjö (2015) stated that the construction logistics also involved various site services which important to a functioning project such as site security, cleaning, walkways, signage, vertical lift, staff welfare, traffic management, health and safety and etc, but exclude those site services in actual construction work.

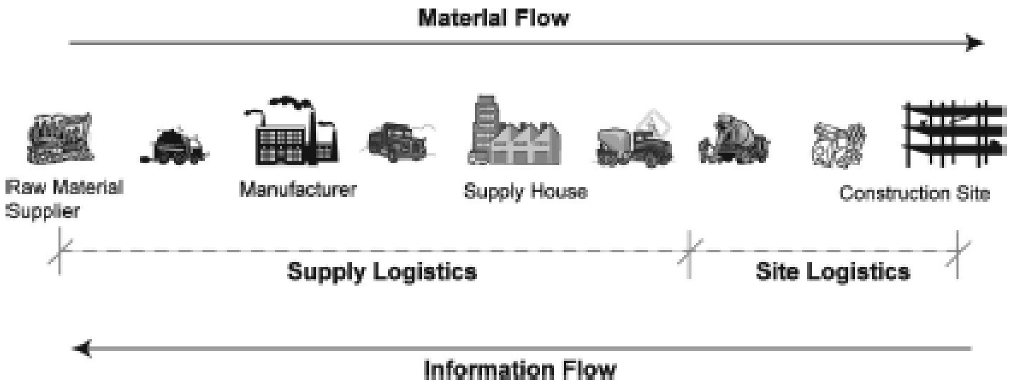


Figure 2.3: Activities Involved in Construction Logistics
(Source: Jang and Russell, 2003)

Refer to Figure 2.3 above, construction logistics generally can be categorised into 2 types which are supply logistics and site logistics. Supply logistics engaged operations pertaining to acquisition, specification, transport as well as materials' delivery to the construction site when site logistics is related to planning of physical flow and handling of materials on site (Sundquist, et al., 2018). However, Moone (2015) described the construction logistics' concept is not only limit to deliver the construction material to the boundaries of construction site. It is an equally essential to distribute the materials inside the site and ensure that the materials able to reach wherever it is needed and whenever it is required (Moone, 2015). Logistics to construction site always need the use the heavy truck and forklift to transport all of the required construction materials for example sand, rock and cement to site (Zuhra Junaida and Nurul Fatimah, 2020). On the contrary, the mode of transportations used inside the construction site can be either vertical or horizontal. It extends from forklift and truck to include those equipment for site confined which are construction elevators and cranes (Moone, 2015).

2.5 Problems of Construction Logistics in Current Practices

There is a bright future to look at the construction industry for example increasingly investment as highly demand in housing, infrastructure or service project. However, McKinsey Global Institute (2017) viewed that the productivity of construction industry only grows for 1% annually in the past 20 years. The inefficiency and low productivity in delivering project has suffered by construction industry for decades and it may cause by the poor performance or management of construction logistics activities in current practices (Bomb and Haraldsdottir, 2017). Thus, the effectiveness and functioning of current practices adopted in construction logistics have been interrogated by numerous researchers from worldwide. The problems of construction logistics in the current practices include cost overrun, impact to people, impact to environment, health and safety of workers and lack of collaborations. The literature reviewed for these problems are presented in Table 2.1 below.

Table 2.1: Literature Review for Problems of Construction Logistics in Current Practices

Problems of Construction Logistics in Current Practices	Previous Studies														
	Salvén, 2013 (Sweden)	Browne, 2015 (UK)	Matouzko, 2015 (Sweden)	Nuran, 2015 (Malaysia)	Perugu, et al., 2016 (US)	Ekeskär, 2016 (Sweden)	Mesjasz-Lech, 2016 (Poland)	Hsu, et al., 2017 (UK)	Tsaxiri, 2018 (Sweden)	Hsu, et al., 2019 (UK)	Zhang, et al., 2019 (China)	Telese and Hedlund, 2019 (Sweden)	Peng, et al., 2019 (Australia)	Zuhra Junaida and Nurul Fatimah, 2020 (Malaysia)	Pamela, 2020 (Austra)
Cost and Time Overrun	✓	✓	✓			✓		✓							✓
Impact to People				✓						✓					
Impact to Environment					✓		✓			✓	✓		✓		
Health & Safety Problems	✓													✓	✓
Lack of Collaboration									✓						

2.5.1 Cost and Time Overrun

Poor logistics management will cause various needless production costs and extra time needed for awaiting the arrival of materials (Matouzko, 2015). Furthermore, theft and misplacement of materials may be happened which contributes to unexpected costs for transportation (Abeysinghe, et al., 2018). In a similar way, Ekeskär (2016) stated that less than 50% of the deliveries of the construction logistics can provide delivery free from damages and in the correct amount, to the correct location and within time plan.

Next, total demand of modular components is uncertain until their completion of assembly at the site because there are many sources of delay to be exposed in the assembly process like delayed shipment, extreme weather conditions, equipment failure or human errors (Hsu, et al., 2019). For instances, modular products like kitchen pods or bathroom always are project-specific and tailor-made, thus when the manufacturer fails to meet the demand, these modular products typically impossible to be procured from other manufacturers (Hsu, et al., 2017). Due to this, incidents such as excessive on-site inventories or insufficient delivery for components always reoccur weekly until the project is completed (Hsu, et al, 2019). This effectiveness has caused the production to stop and boost those non-value adding or unnecessarily activities (Matouzko, 2015).

2.5.2 Impact to people

Sleep disturbance and annoyance resulting from transportation noise pollution are always related to heavy construction vehicles. Road logistics is essential and beneficial to the economy and community; however, those live near or along the logistics routes are adversely affected by these heavy trucks (Peng, et al., 2019). Furthermore, Nurain (2015) viewed that many drivers of heavy vehicles will locate their truck on the road shoulder or lane of neighbourhood street when they unable to find parking lot. This action is unsafe as may bring potential safety hazards to themselves as well as other drivers, pedestrian and motorcyclist. Many road users typically have negative impression or experiences towards the heavy vehicles when these trucks become an impending vision or obstruction for them. On 3 March 2021, a fatal accident of 2 women were happened due to a trailer lorry hit the scaffolding of pedestrian bridge and finally cause the collapse of a bridge section (The Straits Times, 2021).

On the other hand, several federal roads are severely damaged by those overloaded heavy trucks. These potholes created may pose danger to other road users and accidents may happen (Nurain, 2015). These potholes have caused approximately 4,000 cars seriously damaged every month and there are 24 cyclists fatal on earlier July (Woodling, 2020).

2.5.3 Impact to environment

Logistics vehicles are one of the main root causes of air pollution in urban area (Mesjasz-Lech, 2016). Marsal-Llacuna, et al., (2015) stated that air quality is one indicator in Local Agendas 21 (LA 21) to determine a city's sustainability at a local level. However, several cities face seriously air pollution with the fine particulate matter (PM2.5) which is the one of the main specific pollutant (Zhang, et al., 2019). With exposure to air pollution which is caused by PM2.5, many negative health effects will be confronted such as mortality from respiratory or cardiovascular disease even from lung cancer (Bell and HEI Health Review Committee, 2012).

Perugu, et al. (2016) stated that heavy vehicles contribute as the highest on-road emitters of PM2.5 and estimate that the heavy trucks activities contribute about 71% of PM2.5 to urban areas. Furthermore, the emissions of black carbon (BC) and other gaseous pollutant have significantly increased by heavy vehicles (Zhang, et al., 2019). Most of the heavy vehicles are primarily powered by diesel fuels which produce nitrogen oxides and articulate matter eventually pollute the air (Hsu, et al., 2019). Moreover, United States Energy Information Administration (2020) also stated that transportation is the greatest sources of air pollutants which cause global warming.

2.5.4 Health and safety of workers

Salvén (2013) stated that the time of workers spent on replacement of the materials on site is roughly 14% of their total working time. These actions include shifting the materials back to storage area, bringing the materials from this place to other site and moving the right materials from the store to wherever the materials are really needed. With poor logistics, the construction workers are observed to be more stressed and unconfident on-site because they need to work in limited working space when other spaces are used for storing materials (Salvén, 2013). Furthermore, Health and Safety Executive (2020) stated that there are almost 7 workers fatal in accidents which involved the mobile plant or vehicles on site every year and further 93 are severely injured. For example, Pack (2020) reported that a worker died on 17 July due to several blunt force injuries after a dump truck backed over him in construction site.

2.5.5 Lack of Collaborations

It is estimated that the subcontractors help in producing works which exceed 75% of final value in a typical project (Segerstedt and Olofsson, 2010). However, when a huge number of subcontractors involved a large project, each of them only manages their own material flow respectively and do not coordinate with other members (Robbins, 2015). Tsaxiri (2018) stated that during the timeline of a project, conflicts will happen between different parties because each of them does not pay attention to manage the logistics activities. Poor collaboration and conflicts between parties is quite common in construction project (Tsaxiri, 2018). This scenario has caused severely problems in managing the construction logistics and eventually exceeds the time plan and budget due to improper logistics solutions (Robbins, 2015; Ekeskär and Rudberg, 2016).

2.6 Benefits of Logistics 4.0 in Construction Industry

Logistics have gone through three revolutions in the past. The Logistics 1.0 happen from the late of 19th century until early 20th century which is driven by "mechanization of transport". The second revolution from the 1960s is caused by "automation of handling system". From 1980s, the Logistics 3.0 is driven by "the logistics management system" (Wang, 2016). In 21st century, Logistics 4.0 is triggered to meet those floating challenges for example market's permanent volatility, high-individualized products' demand, increasing international competition and shorter product life cycle (Qu, et al., 2016). Especially, logistics is an essential profitable element in the Global Economy as it is recognised as the source to achieve a competitive advantage. Thus, in order to survive and compete in global market, the industries should be logistics-oriented (Werner-Lewandowska and Kosacka-Olejnik, 2019).

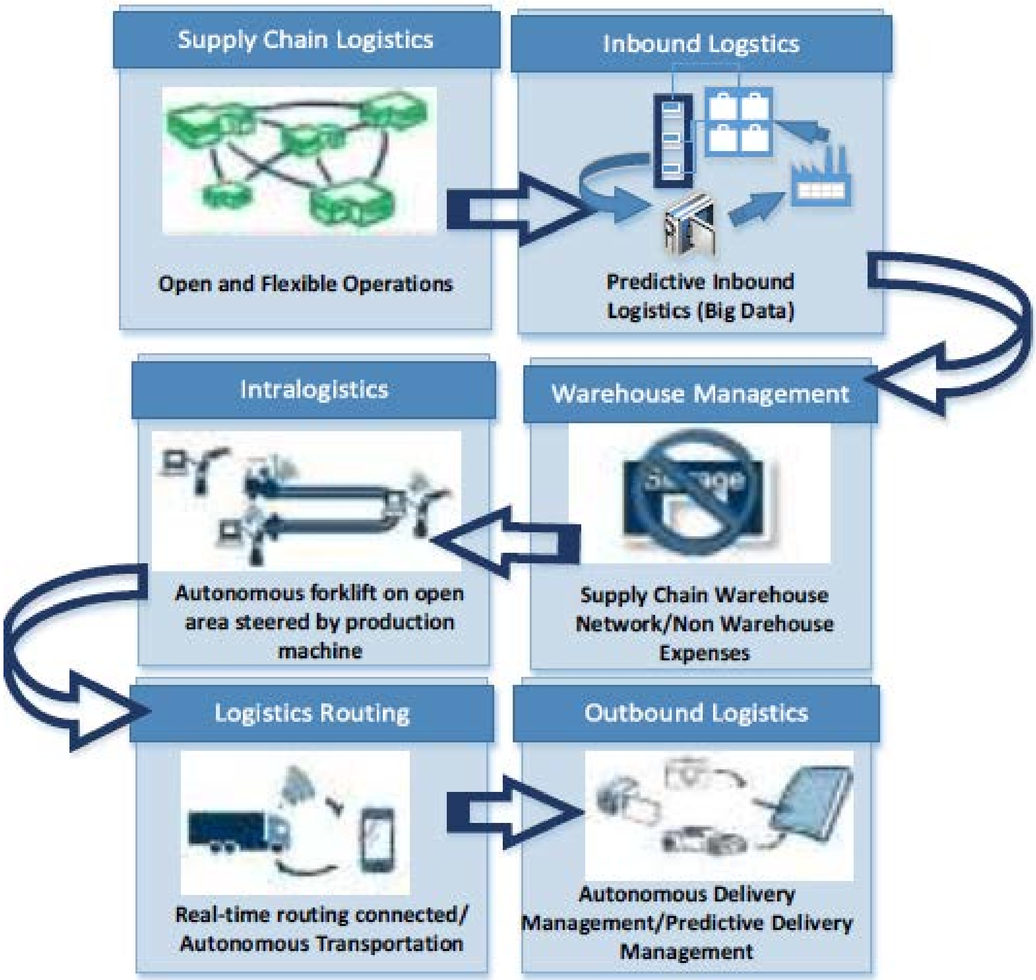


Figure 2.4: Supply Chain Management by Logistics 4.0
(Source: Wang, 2016)

The society is altering towards to connect humans, machines and objects closely (Schemidtke, 2018). Most of the industries have undertaken an evolution by instilling these technology innovations into their process and product for their operations' core (Wang, 2016). Due to this, the supply chain logistics in Logistics 4.0 is performed with the aid of technology as illustrated in Figure 2.4. The literature reviewed for some of these technologies adopted in Logistics 4.0 are presented in Table 2.2 below.

Table 2.2: Literature Review of Technologies Adopted in Logistics 4.0

Technologies Adopted	Previous Studies												
	Wang (2016)	Galindo (2016)	Strandhage, et al. (2017)	Barreto, et al. (2017)	Oleśków-Szłapka and Stachowiak (2018)	Sternad, et al. (2018)	Glistau and Coello Machado (2018)	Schmidtke, et al. (2018)	Maskuriy, et al. (2019)	Matyushenko, et al. (2019)	Werner-Lewandowska and Kosacka-Olejnik (2019)	Klumpp (2020)	Facchini, et al. (2020)
Artificial Intelligence (AI)	✓		✓		✓			✓	✓	✓	✓	✓	
Big Data	✓	✓	✓				✓	✓		✓	✓		
Cyber-physical system (CPS)	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Cloud-supported network or computing	✓		✓		✓		✓	✓			✓		
Extended producer responsibility (EPR)				✓	✓	✓			✓		✓		
Internet of Things (IoT)	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓
Radio-frequency identification (RFID)		✓			✓		✓			✓	✓		✓
Real-Time Location System (RTLS)	✓		✓		✓			✓			✓		

From Table 2.2, it can be claimed that Logistics 4.0 is a quite new topic as the oldest research were published in 2016. Traditional logistics practices start to be improved and modified by these technologies-driven approaches to fulfil the rule of 8R which refer to Right time, Right place, Right quality, Right quantity, Right price, Right customer, Right Product, Right place (Lewandowska and Olejnik, 2019). In other words, Logistics 4.0 turns traditional logistics into digitalised, automated and organisationally transformed (Sternad, et al., 2018). However, Livotov, et al. (2019) stated that the construction industry has not kept trend with these technological opportunities which can improve productivity and production. In this uncertain and dynamically changing environment in logistics sector, it becomes more and more difficult to fulfil the rule of 8R (Wang, 2016). Thus, there are some benefits or potentials for the construction industry to innovate with these technologies.

2.6.1 Improve Productivity

The adoption of AI and automation in logistics ensure the cooperation between different players more aligned within transportation and operations processes, for example between production, picking and outbound logistics (Schmidtke, et al., 2018). As a result, picking time and the cycle times of inventories can be significantly reduced by using AI-controlled technologies. On the other hand, the AI controlled-networked robots can ensure the communication between supervisors and warehouse employees is error-free and simultaneously, in order to respond more precisely to any disruptions or changes of order (SSI Schaefer Whitepaper, 2018). As consequences, lead times of logistics activities may significantly be reduced (Schmidtke, et al., 2018).

2.6.2 Save Cost

Through implementation of Logistics 4.0, it is potential to save 20% cost in supply chain, maintenance and quality as well as 30% inventory costs. With the aids of technology, when a vast amount of data for planning and forecasting algorithms are provided, suppliers able to enhance their forecast of shipping and demand, identify possible market's improvements and potential loss. It means suppliers less prone to failures, risks and opacity (Matyushenko, et al., 2019). Furthermore, due to process of customer's order and the order to supplier simultaneously, the expenses used for warehousing can decrease to the minimum and even no need for preparing warehouse (Wang, 2016). Cost savings can also be achieved when AI application is adopted in the area of personnel works as automated intralogistics, robotics and logistics application able to provide solutions which are more durable, faster and therefore eventually cheaper to the logistics domain (Klumpp, 2018).

2.6.3 Increased Earnings

The volume of revenue will be increased by AI applications in many ways whether indirectly by matching the customers or products' preferences, expectations and specifications better to ensure the satisfaction of customers and the rates to re-buy; or directly avoiding the materials from out of stock and make sure the products are available at the point of sale as the exact date of arrival of materials for production can be estimated in order to prepare for final product (Barreto, et al., 2017; Klump, 2018).

2.6.4 Improve Efficiency and Effectiveness

Thus, big data and Internet of Things and Service (Iot&S) both are the main innovations in Logistics 4.0. Both of them can reduce human intervention in each steps of work in supply chain. Each process which is completed or operated through human's decision-making is replaced by those new technologies for example warehouse robot and automated guided vehicle (AGV) when AGVs, autonomous forklifts or programmed robots can automate to complete the intralogistics of the goods within the factory themselves. Furthermore, all of the orders from the big network (from customers or from suppliers) can be managed by an internet platform online or in real time. All logistics activities from the internet platform will be used by entire stakeholders. By the use of internet platform, logistics vehicles will possess a routed program which will provides all necessary information and vehicles which possess RTLS are able to be tracked by the suppliers and customers (Wang, 2016).

2.6.5 Improve Transparency and Flexibility

It is necessary for logistics sector to respond to the growing pressure for transparency and flexibility which resulting from the increasing competition in global market (Sternad, et al., 2018). Transparency which potential to enhance the comprehensiveness of logistics can be improved through advanced analytical works which involved data collection using NFC tags, sensors or RFID chips (Matyushenko, et al., 2019). Furthermore, AI applications can improve the flexibility of transportation setup and intralogistics which may especially be fundamental in peak times of logistics environment, for instances when delay or other complex ‘troubleshooting’ incidents occur. In such situations, AI can make fast decisions independently in order to maintain the satisfaction of customers as well as the competitiveness between suppliers, manufacturers or other logistics service providers (Klumpp, 2018).

2.6.6 Higher Safety

National Science & Technology Council and United States Department of Transportation (2020) stated that U.S government has stressed in developing Automated Vehicles (AV 4.0) in order to ensure the roadways safer by decreasing crashes resulting from poor human choices or human errors, comprising crashes caused by distraction or impairment when driving. In short, safety is the main component for incorporating the AVs into the transportation system. On the other hand, in order to improve the site safety and reduce site accidents, Volvo Construction Equipment (CE) collaborates with Colas to develop an integrated AI algorithm innovation which will detect and warn when people are entering into a dangerous zone (Volvo CE, 2018).

2.6.7 Environmentally Friendly

According to National Highway Traffic Safety Administration (2013) of America, "Automated vehicles are those in which at least some aspects of a safety-critical control function (e.g., throttle, steering or braking) occur without direct driver input." AVs utilise the alternative fuel such as electric power or gas. Such way to empower the vehicles reduces the dependency of vehicles on fossil fuels and eventually brings a positive impact on the amount of greenhouse gas emissions such as carbon dioxide. Chen, et al (2017) mentioned that AVs can save fuel consumption from 30% to 45%. On the other hand, Iglinski and Babiak (2017) stated that vehicles will consume 50% more fuels when congestion. Thus, in order to reduce congestion level, AVs are equipped with technology enabled interactions with other vehicles and real-time information is provided on level of congestion or accidents, then it will have own decision-making to select the route in order to avoid congestions and eventually reduce emissions and fuels (Kopelias, 2020).

2.7 Adoption of Artificial Intelligence in Construction Logistics

It is obvious that construction industry has vast potential when the construction sector today holds about 13% global GDP that worth roughly $10 trillion. By the year 2030, the value is estimated to achieve $17.5trillion (McKinsey Global Institute, 2017; Maskuriy, et al., 2019).

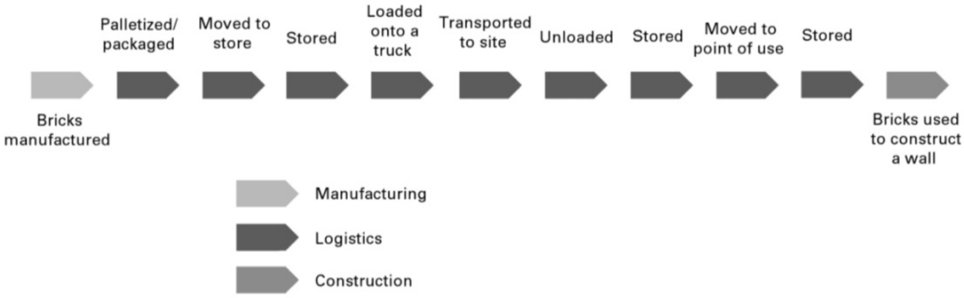


Figure 2.5: Logistics in building a block wall

(Source: Lundesjö, 2015)

Figure 2.5 illustrated the example of logistics process when construct a block wall, it is clearly illustrated that around 80% of construction activities are related to logistics (Lundesjö, 2015). Similarly, Sundquist, et al. (2018) viewed that logistics activities are intensive and may have about 100,000 deliveries within a period from 12 up to 18 months. In short, construction logistics is definitely crucial in supporting the rapid economy and development (Zuhra Junaida and Nurul Fatimah, 2020). The followings examples of existing AI applications which are gradually be adopted in the presence or future of construction logistics.

2.7.1 Automated Guided Vehicles

AGV is an ideal solution for repetitive transportation works in warehousing and production operations. It mainly provides the point-to-point transferring of racks, pallets, skids, rolls and tubs by utilised automated pick-up, transfer and drop-off. Figure 2.6 shows the working environment of AGV with other mobile robots. AGV with natural features navigation can offer user faster setups on-site with more accurately and safer navigation by mapping their paths to travel without any human assistance. The throughput and uptime can be enhanced by its capabilities to automate battery charging and operate for four hours per each battery charging (Modern Material Handling, 2020).

The latest guidance algorithms developed in AGV is vision-based system with neural network. They can detect the obstacles by using their navigation equipped with external sensor which can capture information with proximity visual image and measurement (Das and Pasan, 2016). Thus, when swarms of AGVs work together, they still can recognise their environment independently with each other by navigating autonomously the route to reach their respective destinations. Although there is no central control system by humans or computers, AGVs still can control the incoming transport order themselves by establishing rules in finding the right route and share their location with one another. It means swarm of AGVs react and undertakes problem solving independently (SSI Schaefer Whitepaper, 2018). In short, AGVs improve effectiveness of material handling by performing safer, at low cost, accurately without any damage on materials and at timely manner (Das and Pasan, 2016).

Figure 2.6: Working Environment with AGV
(Source: SSI Schaefer Whitepaper, 2018)

2.7.2 Unmanned Aerial Vehicles and Unmanned Ground Vehicles

For fully autonomous warehouse inventory, the unmanned aerial vehicles (UAV) (also known as drones) and unmanned ground vehicles (UGV) are both great candidate for replacement of humans works. The UAV is utilised as the mobile scanner when UGV is utilised as a carrying platform. Firstly, the navigation is carried out by UGV among the racks' rows. It is important to note that UAV will follow UGV autonomously all the time because UGV acts as its ground reference. Next, UGV will stop at each rack to be scanned. At the same time, UAV will take off and fly vertically to scan each goods in that rack. Once the UAV reach the top, UGV will move to next rack. At this time, UAV is located at the top of the rack, thus it will scan the goods from top to bottom. These steps repeat until all rows are fully scanned. On the other hand, UAV can recharge its batteries by landing on the UGV when UGV is moving to next racks (Guérin, et al., 2016).

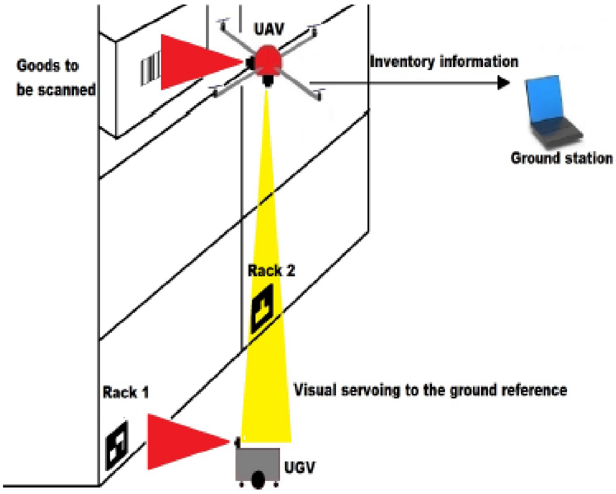


Figure 2.7: Autonomous collaboration between UAV and UGV

(Source: Guérin, et al., 2016)

Refer to Figure 2.7, an UAV and an UGV work cooperatively in tracking the inventories. This drone-driven automated inventory warehouse system is enabled by the cooperation among bar codes, QR codes, new scanning technologies, RFID technologies and especially AI. Efficient AI algorithms and onboard computing power allow the drone can operate in the warehouses which are diverse complex-structured in terms of type of stored items, geographic location and layout (such as pallets, shelf and boxes). Through the adoption of these technologies, inventory accuracy can be increased, labour costs significantly decrease, dangerous tasks in working high altitudes for the workforce can be minimized and faster in counting than human (Wawrla, et al., 2019).

2.7.3 Autonomous Truck

AI is the core technology for Level 4 autonomous driving which able to drive on their own without any driver monitoring or input over designated route (Transport Topics, 2018). Figure 2.8 showed Volvo Vera which is the first autonomous, connected and electric vehicles presented by Volvo Trucks in 2018 to create part of an integrated way in transportation of goods from a logistics central to a terminal port for delivery across the world. Vera is designed for repetitive works in factories, logistics centre as well as ports by transporting vast amount of goods with high preciseness.

Figure 2.8: Volvo Vera

(Source: Volvo Trucks, 2019)

Now, Volvo Trucks is aiming to further develop its potential by implementing a connected system comprising of numerous Vera monitored by a controlling tower, in order to enable a constant and seamless flow responsive to great demand with higher flexibility, efficiency and sustainability. Mikael Karlsson who is Vice President of Autonomous Solutions in Volvo Trucks stated that testing has been started in developing the autonomous transports with zero exhaust emission and low noise level (Volvo Trucks, 2019).

2.7.4 Unmanned Tower Crane

One of the most important lifting equipment in construction site is tower crane especially in the high-rise building construction work. The duration and expenses of a project highly depends on the operators' ability and it is a dangerous work. Thus, there are some elemental technologies related to AI are used to develop the unmanned cranes (Ahn, et al., 2018).

The adoption of voice recognition technology and classification technology make unmanned crane able to recognize and act the orders after commands are given through a radio. The sound waves are learned in order to recognize voice. The accuracy of voice recognition is high even in the noisy construction site (Ahn, et al., 2018).

On the other hand, the number, location and model of a tower crane will bring significant impact to construction duration and expenses. Although an advanced tower crane can decrease construction time, it will boost the daily tower crane's rental fees. Genetic algorithm by AI is the proper means for optimization by automatically calculating the minimum total rental expenses by changing the model, number and location of the tower crane (Ahn, et al., 2018).

2.7.5 Smart construction lift

The higher the building built, the bigger of volume and types of materials needed to be transported. Construction lift is important to maintain or increase the efficiency of the site logistics. However, there are always various variables and inaccurate prediction for logistics plan in dynamic construction site. Therefore, smart construction lifts which can operate itself efficiently is needed (Ahn, et al., 2018).

For example, by adopting logical algorithms, the lift can recognize the schedule by itself and always stand by to execute the scheduled task. Furthermore, recurrent neural network (RNN) can reflect on the latest time series data and forget the remote past data. The input data is time and number of driving, arrival floor as well as starting floor themselves by. Then, by learning these huge volume of data, the running zones can be decided by the lifts themselves (Ahn, et al., 2018).

2.7.6 AI-Based Drones

The traditional way to gather information for site layout plan is personnel walks around the site by foot, manually collecting the information as he goes. It is slow and labor-intensive and cannot react promptly to the ground changes especially after raining which potential to cause delay for a construction project. However, a lot of improvements in construction have been help by drones in the past few years in order to increase the speed, report accuracy, costs cutting, efficiency and safety (Dukowitz, 2019).

Drones typically equipped with radar, video cameras, communication hardware and wireless sensors for transferring real-time data (Gheisari and Esmaeili, 2016). Nowadays, drone technology has been developed along with AI-driven software which is a powerful system to process the raw visual data input from drone and finally a details maps of construction sites can be provided. When drone is flying, it can capture visual footage continuously and constantly; eventually be processed automatically by AI software which capable to produce different types of maps for whole site in the end. Furthermore, the detailed visual reports provided by drone can be shared among each project participants (Dukowitz, 2019). On the other hand, drone is the best participate to safety manager by providing site's maximum visible angle for 24 hours inspecting, monitoring, controlling activities, machinery and people on site (Gheisari and Esmaeili, 2016).

2.7.7 Predictive Analytics

Predictive analytics is the traditional use of AI which mainly based on data mining. It involves pattern detection by fed a volume of data and statistical calculations. AI can help to reduce the uncertainty in logistics industry by dramatically varying its operating model from forecasting and reactive mode to proactive actions with predictive intelligence (Gesing, et al., 2018). Descriptive analytics is the preliminary stage which used to characterise, categorise, consolidate and classify data in order to get valuable information in identifying and understanding the problems; when prescriptive analytics is the subsequent stage which makes use of the data mining and statistical techniques in predicting the future by using analysis of past performances such as historical data is examined, patterns are identified, and the relationship is extrapolated. Algorithms are applied on datasets by predictive analytics for exploring and examining the decisions potential which related to complex and high-volume requirements and objectives for optimizing performance (Ngo, et al., 2020).

Predictive network management can be carried by machine learning-based tool in order to make proactive mitigation when freight transit time is predicted to be delayed. This tool also can identify the top factors of causing delay to ensure planning ahead. Furthermore, AI is used in predictive risk management to mitigate the problems with suppliers like poor labour practices to materials shortage, by using the power of AI like natural language processing and advanced machine learning. AI will monitor the information then identify the risk indicators and finally make earlier corrective actions to avoid logistics disruption. On the other hand, AI can also make intelligent route optimisation which is important for logistics providers in transportations, picks up and shipments (Gesing, et al.,2018).

2.7.8 AI-powered Jobsite Cameras

Jobsite cameras powered by AI with advanced video analytics will allow capturing of image and video automatically, processing the images into useful information and real-time detection of things and events of interest on-site can be provided. It is useful in ensuring site security, safety of workers and also analysing the flow of materials on site. It acts a deterrent in reducing the theft of materials on-site (Gaw, 2019).

2.7.9 AI Back Office

Cognitive automation (intelligent or smart automation) is process automation by using the combination of robotic process automation (RPA) and AI. Cognitive automation tools able to handle unstructured information and decisions can be made based on unstructured and complex input. Those clerical labours are replaced by the software robots which integrated with the IT system and existing business applications. RPA is different with AI. RPA unable to learn beyond its initial specified programming and only can operate those rule-based works which have been well-structured inputs by humans; AI is able to extract and learn itself from the unstructured data (Gesing, et al., 2018).

First, the combination of RPA and AI can well-cooperated in detecting fraud when logistic service providers always depend on numerous third parties in project. Millions of unstructured invoices need to be processed by logistics accounting teams annually. AI natural language processing (NLP) can help to reduce this burden by understanding the unstructured data from emails and extracting the crucial information for example parties involved, account information, billing amounts, dates and addresses. After AI well classifies the data, the data is fed into the existing accounting software by RPA in order to generate an order, payment and confirmation email to customers. All these processes can be done without any human intervention (Gesing, et al., 2018).

Sometimes, when there are physical documents such as printed contracts or handwritten invoices which are hard for a machine to understand, with aids of optical character recognition (OCR), it can be converted into machineencoded text which can be processed by machines as well as consumed and editable by humans. However, OCR’s rate of accuracy is depending on the quality of original document and sometimes it is problematic as small mistakes such as incorrect price or address may cause significant loss. Traditional OCR is manually check and monitor its results when AI can do this automatically by pulling insights itself from the text (Keary, 2019; AI Mutiple, 2021a). Thus, AI product with the ability of invoice capture is the first purchase by most of the companies because it is easy integration with significant benefits (AI Mutiple, 2020, AI Mutiple, 2021b).

Second, cognitive contracts can be completed by using AI natural language processing in classifying any policy-relevant sections, contractual clauses and signature portions. Furthermore, one of the most crucial parts in logistics industry is keeping the information like address up to date and complete. Now, an AI engine has been developed to manage and minor pre-processing the contact information in order to ensure the correctness, completeness and consistency of billions of data (Gesing, et al., 2018).

2.7.10 AI Developer Kits

AI developer kits such as the Jetson AGX Xavier developer kit in Figure 2.10 which is the first computer in the world specially designed for autonomous machines, drones and robots. The AI of power is brought along with excellence performance in handling sensor fusion, obstacle detection, localization visual odometry, path planning and mapping algorithms. End-to-end AI robotics applications becomes easier to be created and deployed by people. It supports last-mile delivery as it is multi-algorithm and real time processing to navigate the crowded and populated area. In warehouse logistics, this computer vision and advanced AI processing enable object recognition, navigation, data security as it can be embedded in AGV or UAV. On the other hand, aerial and stationary cameras powered by this developer kits can perform inspections, vehicles tracking and unauthorized visitors in secure areas will be alerted (NVIDIA, 2020).

Figure 2.9: NVIDIA Jetson AGX Xavier developer kit
(NVIDIA, 2020)

2.8 Challenges on Artificial Intelligence Adoption

Although AI is powerful and benefit the industry, there are several barriers or challenges required to be addressed before the adoption of AI. The literature reviewed for these challenges is presented in Table 2.3 below.

Table 2.3: Literature Review of Challenges on AI Adoption

	Previous Studies								
Challenges on AI Adoption	Dietvorst, et al. (2015)	Lauterbach and Bonim (2016)	Prahl and Van Swol (2017)	Omar, et al. (2017)	Tucker, et al. (2018)	Cubric (2020)	Nishant, et al. (2020)	Kaplan and Haenlein (2020)	Cui, et al. (2020)
Algorithm Aversion	✓		✓						✓
Change of Working Culture		✓		✓		✓			
Lack of Leadership Commitment				✓		✓			
Lack of Employees Commitment				✓		✓			
Privacy Concerns					✓	✓	✓		
Environmental Concerns							✓	✓	

2.8.1 Algorithm Aversion

Humans tend to averse to algorithmic forecasters even evidence-based algorithms enable higher accuracy in prediction. It also means that human easily to lose confident when the algorithms make same mistakes (Dietvorst, et al., 2015). Cui, et al. (2020) conducted a research about the impact of using AI in procurement by comparing the quotation price offered by the supplier to human buyers and chatbot buyer (both buyers using AI recommendations). Suppliers will evaluate first whether AI recommendations can influence the decision of buyer. When they know it is a chatbot buyer with AI recommendation, the suppliers will reduce the wholesale price. This is because suppliers believe that chatbot is a machine which has been programmed to follow and trust the AI recommendation. However, when human buyer quotes for prices in person with AI recommendation, suppliers will maintain the price. This is because the suppliers perceive that human buyers will ignore and do not trust on recommendation by AI. Similarly, it is common for everyone such as managers believe more in their own demand prediction than prediction provided by machines; when packing big parcel, workers will use bigger boxes to pack instead of following system suggestion (Cui, et al., 2020).

2.8.2 Change of Working Culture

In order to adopt AI in enhancing the companies' competitive advantages and value, the governance and management of companies will be significantly affected (Omar, et al., 2017). This means the innovation of AI will involve significantly in the decision making, evaluation and analysis process. Many human labours will be reduced and replaced by a machine to boost efficiency and productivity. The working environment may involve more machine or robotic intervention but less human. New innovation is a real challenge for Board members and directors in companies, thus they have to be aware and be ready in diffusion of the AI innovation to survive and compete in the market (Lauterbach and Bonim, 2016; Omar, et al., 2017).

2.8.3 Lack of Leadership Commitment

For the perspective of the top management and directors, they view that AI innovation belong with significant risk, high level of uncertainly and maybe enormous cost which are unable to be estimated. Furthermore, many companies lack of or without capital for AI adoption as AI requires a lot of resources such as research, state-of-the-art facilities and technology advancements. Thus, directors and management might be reluctant to change to avoid the situation cost overweight revenue (Omar, et al., 2017). According to McKinsey Global Institute’s study, there is only tepid demand for AI applications recently because of relatively slow pace of analytics and digital transformation of the economy and many of the leaders all around the world are uncertain about what AI can do for them and whether benefits will be bought along, where to get AI-powered applications, how to integrate it into their company and lastly how to make assessment of return on the investment of AI technology (Bughin, et al, 2017).

2.8.4 Lack of Employees Commitment

Both management and employees are reluctant to change due to many reasons. From the view of employees, AI adoption will be troublesome for them in learning and practicing new skills because the way of producing, delivering of products and services has been significantly changed. Furthermore, unfavourable responses will be triggered by employees as they require to follow the fast pace of continually development and evolvement of AI in order to ensure better performance. They will get stressed because the learning process is long, tough and competitive among employees. On the other hand, AI machine or robots let them feel unsecure as they will be replaced to reduce human errors (Omar, et al., 2017).

2.8.5 Privacy Concerns

There are some examples of privacy concerns by adopting AI which are data persistence, data repurposing and data spill-overs. Data persistence means that once create the digital data, it is difficult to be deleted completely. When data hard to varnish, the uncertainty of how the data will be used will significantly increase. It is still not clear how these data will be used in future. Once created, these data can be repurposed indefinitely. Furthermore, due to the ability of AI to automate prediction and its discriminatory outcomes, algorithms are considered as they will gradually and naturally make spill-overs across data themselves (Tucker, et al., 2018).

2.8.6 Environmental Concerns

AI is not excluded from the distribution of climate change (Kaplan and Haenlein, 2020). Carbon dioxide emitted by a single AI model training is equivalent to 5 cars' lifetime emissions (Hao, 2019). AI models are adopted along with the vast energy consumption big data centres and dataset. Vast amount of energy or raw materials such as nickel, cobalt and lithium are required by the servers which store big data and run computations within the cloud. This raw materials or energy is used for cooling the servers. The enormous amount of these raw materials may soon no longer to be supported by Earth. Furthermore, electronic wastes are produced once they are outdated. These processing may damage the environments further and affect human health (Kaplan and Haenlein, 2020).

2.9 Proposed Theoretical Framework for Artificial Intelligence

In brief, the literature reviewed is summarised into the theoretical framework as illustrated in Figure 2.10. There are 4 moderating variables which have contingent effect in influencing the readiness of industrial players to adopt AI in construction logistics practices. They are the awareness towards "the benefits of Logistics 4.0", the awareness towards "the AI adoption in construction logistics", the current practices of AI in construction logistics and lasty the challenges in AI adoption.

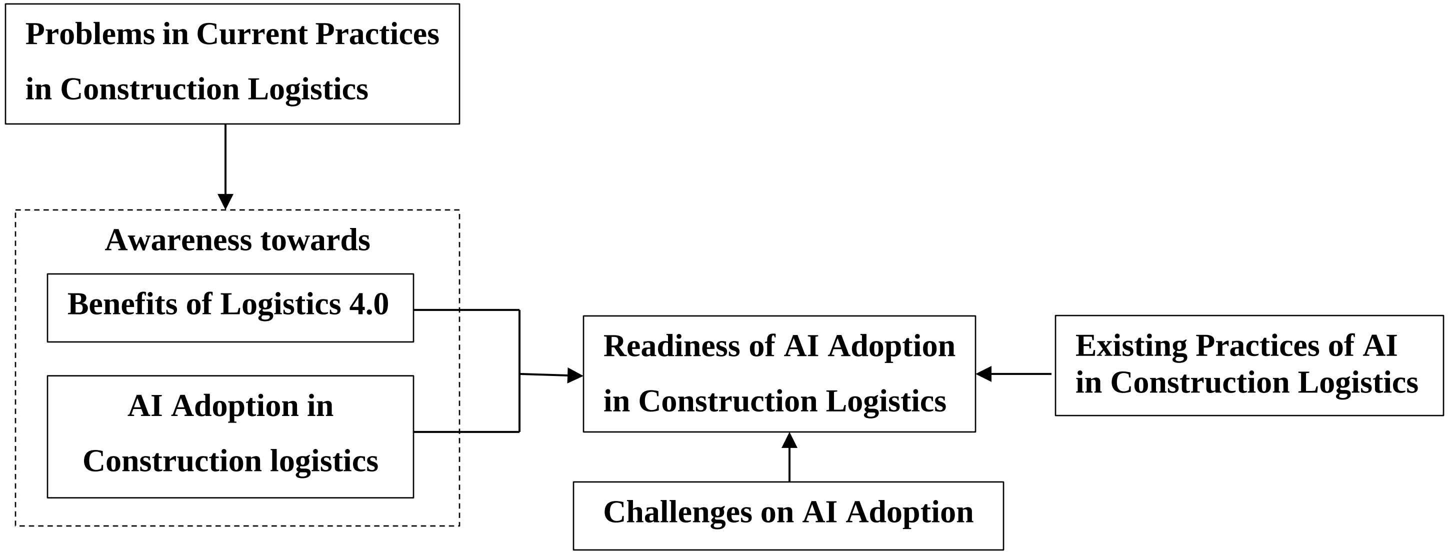


Figure 2.10: Theoretical Framework for AI Adoption in Construction Logistics

2.10 Summary

The chapter disclosed the definition, structure and types of AI. Furthermore, it explained construction logistics and discussed about the problems of construction industry in current practices. It also showed the benefits of logistics 4.0 in construction industry. Lastly, it also reveals the existing practices of AI adoption in construction industry and its challenges faced in AI implementation.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 The Definition of Research

University of Southern California (2015) defined research as “the creation of new knowledge and/or the use of existing knowledge in a new and creative way so as to generate new concepts”. Refer to the Cambridge Dictionary, research was defined as” a detailed study of a subject, especially in order to discover (new) information or reach a (new) understanding.” Furthermore, research means the process of seeking solutions to problems after a thorough and comprehensive study and analysis of situational factors. People are constantly engaging in some form of research activity to explore and examine the issues such as buying a new car, invest a business start-up. Research helps organisations to make proper decisions as good decisions solve the problems and poor decisions persist the problems (Sekaran and Bougie, 2016).

3.2 Research Methods

Research methods are procedure and plans for research which span the steps from general assumptions to detailed methods in collecting, analysing and interpreting the data. In order to obtain better understanding and explanation for research, the empirical data is strived to be collected systematically and the patterns of data is examined. Misunderstandings and miscommunications can be created by the differences between the research methods (Neuman, 2014). There are three types of research method which are qualitative, quantitative and mixed methods (Creswell and Creswell, 2018).

3.2.1 Quantitative Research

The data collection technique in quantitative research involves hard data which always in form of numbers. Typically, this happens by shifting deductively from abstract idea to particular data collecting technique and to exact numerical data. The abstract ideas are empirically represented by these numerical information which represents a standardized, compact and uniform way. Quantitative research uses a language of hypothesis and variables and depend more on positivist principle. It is more emphasis on measurement of variables precisely and hypothesis testing (Neuman, 2014).

For this research, quantitative research method will be adopted to examine the readiness of AI in Malaysian construction logistics. Figure 3.1 shows the steps in quantitative research process. A questionnaire survey is designed for data gathering, analysis and interpretation. Each respondent is requested to answer the questionnaires through Google forms. Statistics are eventually produced from a huge number of sampling group.

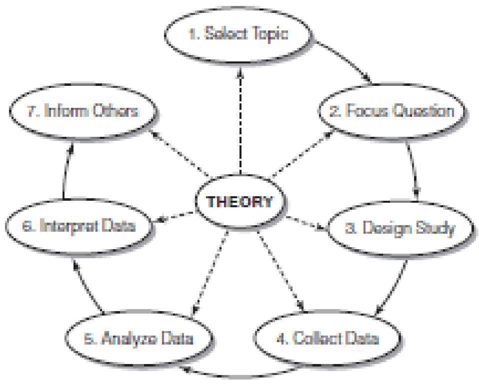


Figure 3.1: Steps in Quantitative Research Process

(Source: Neuman, 2014)

3.2.2 Qualitative Research

The techniques used in qualitative research sometimes involve data in the form of numbers, but more frequently involves soft data in spoken or written words, videos, maps, photos, physical objects, sounds or symbols. Differ with quantitative research, all observations are not converted by a qualitative research into a common, single medium such as numbers, but the data is left in various non-standard sizes, shapes and forms. The qualitative data are diverse, voluminous and non-standard when information is converted into a condensed and standard format by numerical data (Neuman, 2014).

3.2.3 Mixed Method / Triangulation Research

Mixed method is also known as triangulation research which mixes both quantitative research and qualitative research methods and data. Mostly research is developed by an expertise in single method only, however each of the research methods have complementary strengths. By combining both methods, the research tends to be more comprehensive and richer (Neuman, 2014).

3.2.4 Justification of Research Method

For this research, only quantitative research method will be adopted to examine the readiness of AI adoptions in Malaysian construction logistics. Responses or data are collected from the sampling group through online questionnaires. Each respondent is requested to answer the questionnaires through Google Forms only. The data collected by using quantitative research method are analysed numerically and interpreted in the table forms in Chapter 4. Large amount of data is often used to deal in research to achieve results with high reliability. The quantitative data in this research are obtained by preparing a list of relevant questions carefully and distributed to the relevant targeted construction practitioners in Malaysia. After all of the statistical data are received from the respondents, the analysis of data collected are carried out by using Statistical Package for the Social Science (SPSS).

3.3 Research Design

Firstly, the technology today has developed tremendously in many industries especially in construction industry which distributed the one of the highest GDP in Malaysia. Its fast-developing pace has triggered this research which focused on technology in construction logistics as transportation of materials is one the most important factors in ensuring the completion of construction project on time and cost effectively.

It is essential in identifying and narrowing the topic for the research because the scope of technologies used in construction logistics are too broad and too difficult to be studied whole field in a single research. Therefore, AI is chosen as the major technology to be studied in this research., as AI is the major trend throughout 2020 in logistics industry nowadays. AI often appears as the headlines in media recently and many countries have invested in AI, conducted or took part in conference and developed AI Strategy to support the development of AI.

After identifying the research topic, sources of studies then started to be searched and topics related to AI are reviewed. The sources are from journal, online news, book, government websites and official websites. During the completion of literature review, problems for this research is identified concurrently.

It is found that there is no research discussed about the AI adoption in Malaysian construction logistics and its readiness by construction players. Thus, this defined problem is distributed in establishing the aim and objectives in this research in order to minimise the research gap. Thus, this research aims to examine the readiness of AI in construction logistics.

The primary data basically are obtained by using quantitative approaches in order to gain information or data about the current existing practices of AI in construction logistics and their readiness to adopt AI. The respondents are contractors, subcontractors, suppliers, specialists and logistics services providers who have higher level of experiences and involvement in dealing with construction logistics related to back-and-forth transportation of raw material supply, manufacturing factory, supply house, the site boundaries or within the construction site. Furthermore, the secondary data in this research are obtained from online websites, journal, published reports, book, online news and more official sources. Figure 3.2 shows the flowchart of this research.

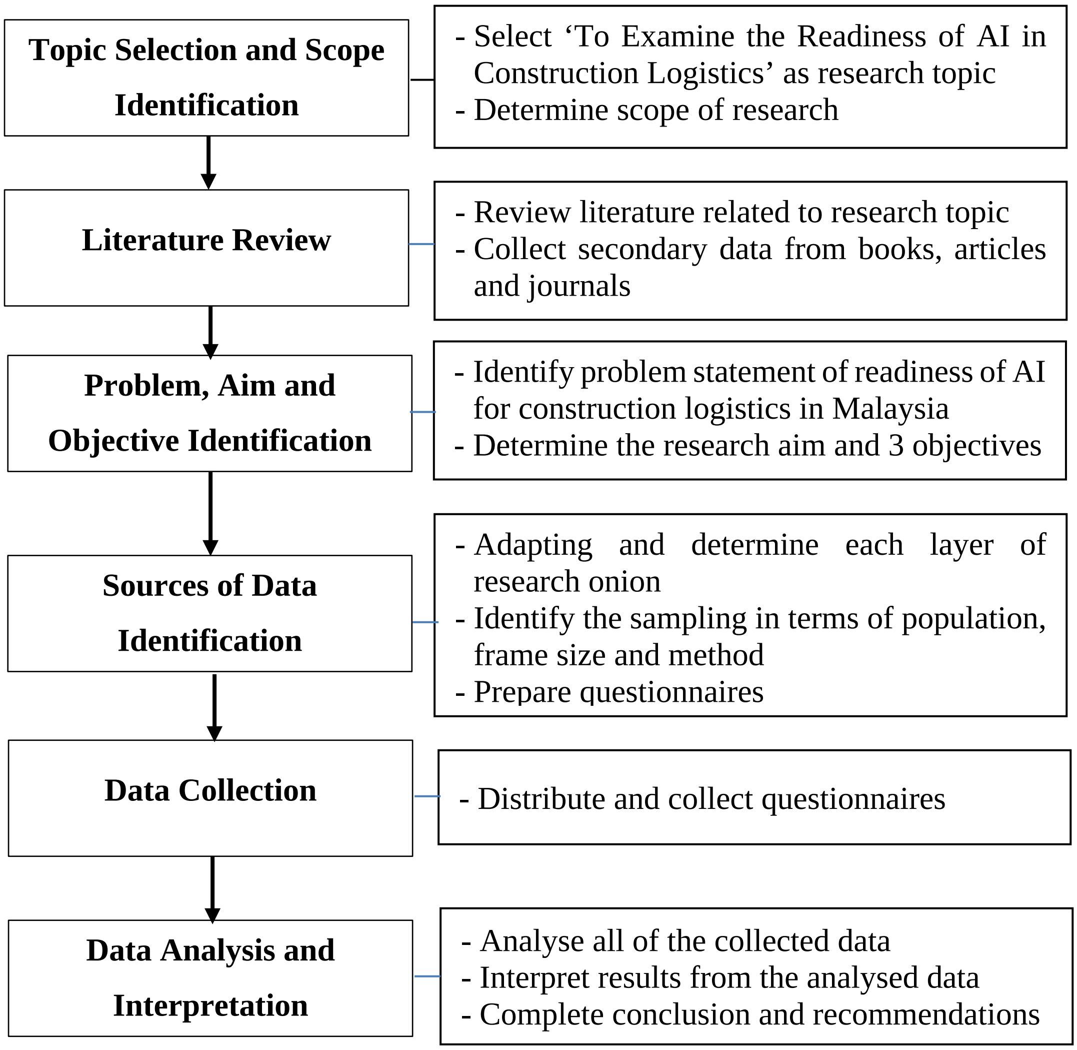


Figure 3.2: Flowchart of Research

3.4 Research Philosophy

The issues underlying the choices of technique in collecting data and data analysis procedures is depicted in Figure 3.3. The philosophy is located in the most outer of the onion’s layer. Research philosophy is defined as assumption about the knowledge development and a system of belief. There are five major philosophies which are positivism, critical realism, interpretivism, postmodernism and pragmatism (Saunders, et al., 2019).

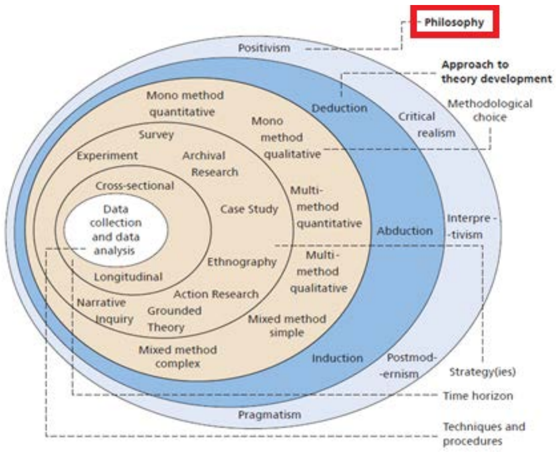


Figure 3.3: The 'research onion'

(Source: Saunders, et al., 2019)

3.4.1 Positivism

Law-like generalisations are produced in positivism research by the philosophical stance of the natural scientist who entailed working with observable social reality. Accurate knowledge and unambiguous are promised in positivism. Human interpretation or bias will not influence the positivist who strictly focus on scientific empiricist method which designed to yield pure facts and data (Saunders, et al., 2019).

3.4.2 Critical Realism

Critical realism focuses on explaining what an individual experiences or sees. However, the most significant philosophical consideration for critical realists is reality, they will see the reality as independent and external. They will not directly accessible via their knowledge and observations to minimise the bias and errors by highlighting how often their senses deceive them. Critical realists will emphasise on those underlying elements in the situations to look for the bigger picture of which they see only a small part (Saunders, et al., 2019).

3.4.3 Interpretivism

Interpretivism mainly emphasises that humans will comes from different physical phenomena which creates various meanings. Different humans will come with different cultural backgrounds, at different times will make different meanings, under different circumferences and different social realities will be experienced. A richer, new and meaningful interpretations and understandings of contexts or social worlds will be created by interpretivist research (Saunders, et al., 2019).

3.4.4 Pragmatism

Pragmatists strive to reconcile both subjectivism and objectivism, values and facts, rigorous and accurate knowledge and different contextualised experiences. Pragmatists will consider the concepts, theories, hypotheses, ideas and research findings and play them as instruments of thoughts and actions. Pragmatists consider reality matters as practical effects of ideas and knowledge as the elements which valued to enable an action to be carried out successfully. Pragmatism research typically will start with a problems and lastly practical solutions are aimed to be contributed to inform future practice. Moreover, pragmatists recognise that there are various ways in interpreting the world as well as undertaking a research, thus there is no single point of view can give entire picture (Saunders, et al., 2019).

3.4.5 Justification of Research Philosophy

In this research, interpretivism is adopted when it provides multiple interpretations, meanings and realities to a research as well as focuses on the new and various perceptions, interpretations, worldviews and understandings to a research. This research requires to seek for different sources which contains various different perspectives, opinions and perceptions from different individuals who have experiences or work related throughout or part of the construction logistics from raw material supplier, manufacturing factory, supply house until construction sites (include boundaries and within site). Furthermore, in order to examine the readiness of AI in construction logistics, interpretivism which value-bound is be prefer when the data will be actively used and attach themselves to their own values and subjectivism interpretations.

The interpretivism philosophy emphasised that different humans with different backgrounds will give different meanings. Thus, survey was targeted and carried out to different industrial players to study their readiness towards AI. In this research, it is not simply discussed whether local construction industrial players are ready to adopt AI in their practices or not. Their readiness is further explained and discussed by its underlying structures which are their awareness towards adoption of AI, current adoption level for existing practices of AI and the challenges in adopting AI such as high implementation cost, lack of support from leaders, lack of knowledge or technologies and so on.

3.5 Approaches to Theory Development and Its Justification

There are three main approaches to the theory development which are deductive, inductive as well as abductive. Deductive reasoning starts with existing theory and always used for theory testing by rising a hypothesis or question. Then, data are collected to reject or confirm that hypothesis. The conclusion from deductive reasoning is logical and true. Other than that, inductive research starts with observations as well as data collection, then begins descriptions and analysis to build a theory. The conclusion from deductive reasoning is logical but maybe false. Abductive reasoning moves between deductive and inductive reasoning is adopted to come up with a best guess and conclusion according to available evidence and incomplete observations (Melnikovas, 2018).

Instead of using deductive and abductive reasoning, inductive reasoning is adopted in this research. Inductive reasoning begins with data collection to explore a phenomenon and theory is generated or built (Doyle, 2020). This research involved down-top thinking of readiness of AI adoptions in construction logistics from specific to general. Firstly, secondary data about the brief account of AI, construction logistics, problems faced in current logistics practices, existing AI adoptions in construction logistics, benefits of Logistics 4.0 and challenges in adopting AI are collected. In order to examine the readiness of AI in local construction logistics, a theoretical framework is created. Overall, a generalised conclusion about the readiness of AI in local construction logistics is reached after identifying the problems of current construction practices, the awareness towards the benefits of Logistics 4.0, the awareness towards the AI adoptions, the existing AI practices and the challenges in adopting AI.

3.6 Methodological Choice and Its Justification

There are five different research choices in terms of qualitative and quantitative research method. As mentioned before in Chapter 3.2, qualitative research method involves mathematical operations and numbers when quantitative research method collects descriptive data. Mono method focused on either one of the research method when mixed method adopts both methods in the same research. Furthermore, the multi-method undermines the function of both choices when both research method is used but one of them is just for supplementary or auxiliary. In this research, the selected methodological choice is mono method quantitative because only focus on quantitative data gathering through questionnaire (Melnikovas, 2018). The details of questionnaires will be discussed later in Section 3.8.1.

3.7 Time Horizons and Its Justification

Time horizons define the research’s time frame. Cross-sectional also knows as short terms study which involves data collection at a specific time only. Longitudinal means the non-stop and repeated data collection over a long time period for completing the data (Melnikovas, 2018). The time frame of this research is cross-sectional only because the data collection only conducted for 7 weeks to complete the final year project 2 (FYP 2).

3.8 Data Collection Approaches and Its Justification

There are two different types of data collection approaches which are primary data collection and secondary data collection. The research design’s integral part is data collection methods. Primary data is collected first-hand with own afford when secondary data is already available or collected by other people or researchers for their purpose. Primary data can be done by observation, interviews, by questionnaires or by experiments to respondents. Secondary data comes from various sources such as government publications, statistical bulletins, unpublished or publishes information available outside or within the organization, Internet or company websites. Some evaluations of secondary data should be done carefully before it is used such as evaluations of the data timeliness (check whether data available is up to date), data accuracy (who and how to collect the data), data relevance (relevant to needs) and data costs (does benefits overweight the costs or it is better off using primary data collection). In the early research process stages such as completing literature reviews, secondary data collection is adopted (Sekaran and Bougie, 2016).

In this research, only quantitative data collection methods have been adopted to acquire broad information on construction logistics. The primary data in this research were gathered through online questionnaires surveys from contractors, subcontractor, suppliers, specialist and logistics services providers who have experiences or work related throughout or part of the construction logistics from raw material supplier, manufacturing factory, supply house until construction sites (include boundaries and within site) while the secondary data were collected by reviewing books, online journals, websites, published reports, online newspaper and so on.

3.8.1 Questionnaire Design

This research's questionnaire is structured into four main sections. The questionnaire design proposed in Figure 3.4 is developed from the theoretical framework shown in Figure 2.10 from Chapter 2. Table 3.1 shows the summary of questionnaire design.

Table 3.1: Summary of Questionnaire Design

Section	Item
A	Respondent's demographic information
B	Artificial intelligence (AI) adoptions in construction logistics
C	Problems in current construction logistics practices
D	Challenges of artificial Intelligence (AI) adoptions

Four questions are set in Section A to collect respondent's demographic data which include business activities of respondents' organisation, the position of respondent in his/her organisation and their working experience in construction industry. All of these are independent variables which used to discuss the relationship with dependent variables which are collected in Section B, C and D. Summary of these assessed questions is shown in Table 3.2.

Table 3.2: Summary of Respondent's Attribute Assessment

No.	Type of Question	Factor Assessed
A1	List Question	Respondent’s organisation business activities
A2	List Question	Respondent’s job position in organisation
A3	Category Question	Respondent’s working experiences

There are total of four matrix questions are set in Section B. There are seven construction logistics activities are listed in B1 and B2 when ten AI adoptions which reviewed in the literature are listed down in B3 and B4. Question B1 and B3 more focused on respondent’s perception towards the relevance and their agreement on the functions of AI adoption discussed in construction logistics. B2 and B4 are more focused on organisation’s plan of AI adoption in construction logistics.

Section C consists of three matrix questions. C1 evaluates the respondent’s perception on problems in current construction logistics practice. Five problems reviewed in Chapter 2 are listed in C1. Next, C2 is focused on the problems faced in current construction logistics practices and have happened to the organisations. C3 evaluates the respondent’s agreement on benefits of Logistics 4.0 in construction logistics practice.

Lastly, section D comprises a matrix question to uncover the factors undermining the AI adoptions. Six challenges from literature review in Chapter 2 are listed and require respondents to rate their agreement towards each challenges of AI adoption. Potential obstacles for AI adoption in local construction logistics are identified through analysis of data collected in this section.

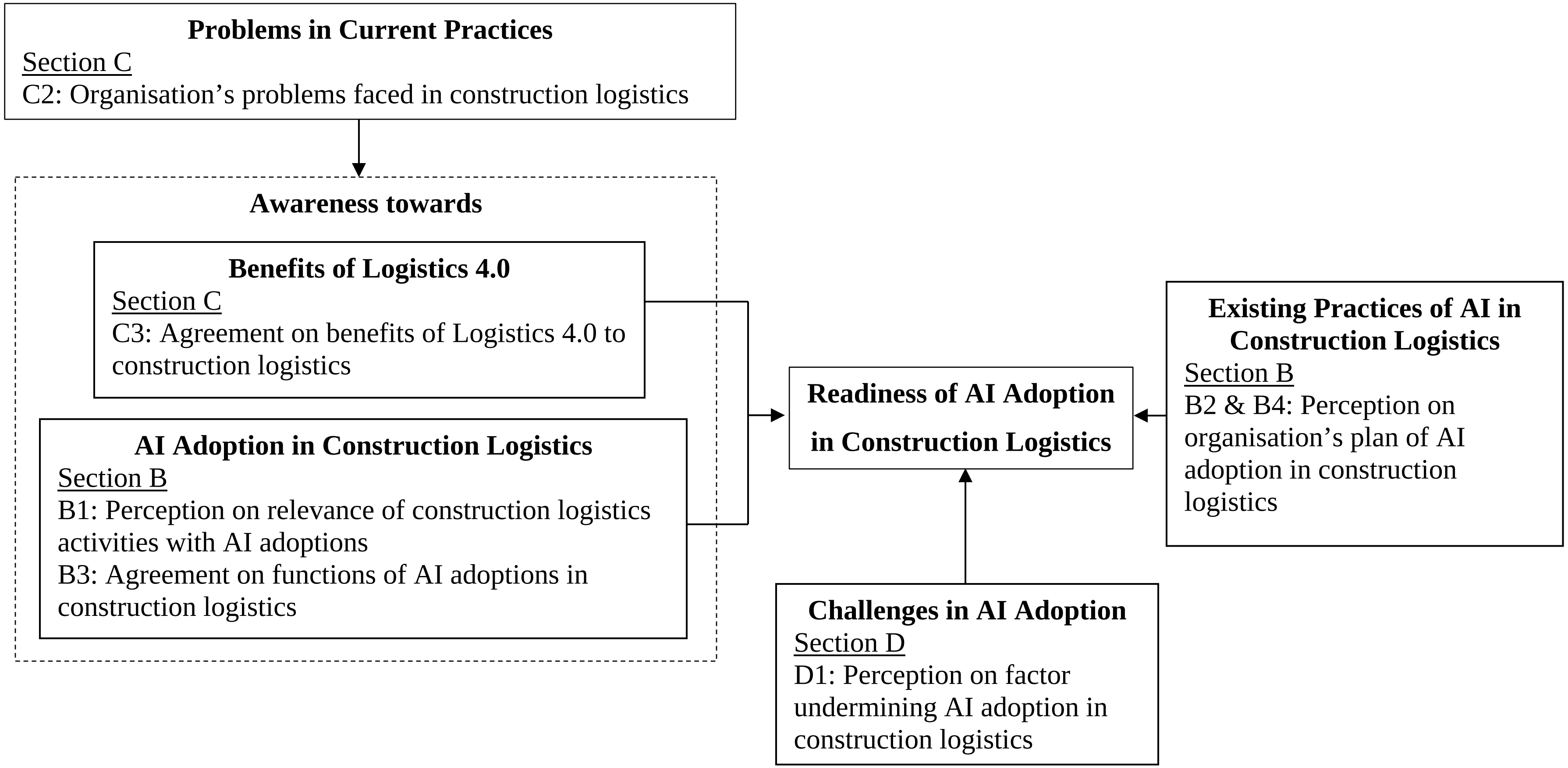


Figure 3.4: Theoretical Framework for Questionnaire Design

3.9 Sampling

Sekaran and Bougie (2016) states that surveys are powerful and useful as a tool to find the answers for research questions by gathering data and subsequent analyses, however if the targeted population is not correct, it does more harm than good and the research is in vain as the collected information cannot provide the right answer in solving the problems. Thus, sampling is important as it involves the selection process of the right people, events or objects as the entire population's representatives. The reason of choosing sampling instead of data collection from the whole population is it may practically be impossible for every element's data to be collected, tested or examined. It is prohibitive in terms of cost, human resources and time. More reliable results are produced by using sampling (Sekaran and Bougie, 2016).

3.9.1 Population

After defining the target population precisely, sampling only will begin. In defining the target population, the scope of study and the research objective play a crucial role. The target population is defined in terms of geographical boundaries, elements and time (Sekaran and Bougie, 2016). The population of this research is individuals working in construction industry or logistics industry throughout Malaysia. They are from different gender, business activities, position and working experience.

3.9.2 Sampling Frame

All of the elements in the drawn sample's population are represented in sampling frame (Sekaran and Bougie, 2016). Thus, sampling frame is one of the crucial considerations to design the sampling. A boundary is set to the sample size from a huge population group. Nevertheless, in a research study, it is possible and always having more than 1 sampling frame due to each sampling frame will bring different types or level of information and perspectives towards the research topic (Turner, 2003).

In this research, there are total of five groups of sampling frame which includes contractors, subcontractors, suppliers, specialists and also logistics providers. In order to examine the readiness of AI in construction logistics, comprehensive information and wide range of perceptions towards the problems in current practices, agreements to benefits of Logistics 4.0, perceptions towards relevance of AI, agreements towards the functions of AI applications, organisation's plan for adopting AI and agreements towards the challenges of AI adoptions are collected from these five groups of sampling.

3.9.3 Sampling Size

Cochran (1977) determined the reasonable minimum sampling size is 384 which can be expressed by the equation below (Cochran, 1977):

$$n = \frac{Z^2 pq}{e^2}$$

$$n = \frac{1.96^2(0.5)(1-0.5)}{0.05^2} = 384$$

where,

n= sample size

At 95% confidence level, Z= 1.96

q= 1-p, p= 0.5, q= 0.5

e= margin of error, normally assume to be 5%

Although larger sample size will provide more accurate information, but finding more respondents is time-consuming. Thus, instead of using determination by Cochran's Formula, the sample size of this research is determined based on the Central Limit Theorem (CLT). If samples' number equal or greater than 30, CLT is reasonably accurate with sufficient size of samples (Chihara & Hesterberg, 2011).

3.9.4 Sampling Method

There are two types of sampling method which are probability sampling and non-probability sampling (Sekaran and Bougie, 2016). Probability sampling is resorted while elements in the population has a nonzero, known chance to be chosen as sample subjects. An equal probability for each element of population is selected into sample by using mathematically random method (Neuman, 2014). Probability sampling can be either simple random sampling or complex probability sampling. Non-probability sampling always creates very nonrepresentative sample while elements in the population has not any probabilities attached to be chosen as sample subjects. Non-probability samples are cheap, quick and easy to obtain as it is not confidently to generalization of the population and this types of samples include convenience sampling and purposive sampling (Sekaran and Bougie, 2016).

In this research, convenience sampling (one of the non-probability sampling method) is adopted in this research when respondents are selected based on availability and convenience in order to examine the readiness of AI in construction logistics. This method is chosen because the units are the easiest to access and this research only interested to achieve enough sample size of 154 individuals to take part (Laerd, 2012). The selected respondents would provide this research with more comprehensive and thorough information because they have higher level of involvements and particular experiences in dealing with construction logistics.

3.10 Data Analysis Method

The data gathered from the questionnaire survey respondents were analysed by Shapiro-Wilk W Test, Cronbach's alpha reliability, descriptive analysis and inferential statistics which is Mann-Whitney U Test. In short, Shapiro-Wilk W test is used to test the normality; Cronbach's alpha reliability test is adopted to ensure the construction of each section in questionnaire is internally consistent; descriptive statistics is adopted to ensure information's plain interpretation and presentation; inferential statistics is adopted to ensure the generalisation of findings.

3.10.1 Shapiro-Wilk W Test

In this research, Shapiro-Wilk W test which is the most powerful numerical normality test in most situation is used. This test is suitable for small sample sizes, for example 50 samples until large sample sizes, for example 2000 samples. The data is normal when significance (Sig.) value is greater than 0.05. When Sig. value is less than 0.05, then the data is deviated from a normal distribution (Laerd, 2018e). In this research, the data gained is non-normal distribution.

3.10.2 Cronbach's Alpha Reliability Test

To measure reliability or internal consistency, Cronbach's alpha is the most common method used while questionnaires have multiple Likert questions and researchers wish to determine whether the scale is reliable or not. For the questionnaire of this research, each of the matrix questions are conducted with Cronbach's alpha reliability test in order to test or measure the internal consistency. Its range of alpha coefficient value is from 0 to 1. The reliable data will show an alpha coefficient value which equal or more than 0.7 (Laerd, 2018b).

3.10.3 Descriptive Statistics

Descriptive statistics makes description, presentation and summary of analysed data in a meaningful way. This statistics is significant when present a lot of raw data because it allows simple interpretations of data. General overview of data results is presented in form percentages or actual numbers (Laerd, 2018a). In this research, descriptive statistics are used for questions in Section A to present the attributes of respondents in form of frequency and also percentage. Moreover, ranking by median and frequency of median are used for questions in Section B, C and D.

3.10.4 Inferential Statistics

a) Mann-Whitney U Test

With median in descriptive statistics, it only shows their rank among the groups, but not pointed which groups are different with other groups. With Mann-Whitney U test, comparison of Section B1 to B4 and C2 are conducted in this research to reject the null hypothesis in order to reveal the significant differences of the pairs of sample groups in terms of their perception.

Table 3.3: Sections for Pairwise Comparison Towards Respondents' Attributes

Section	Table which shows pairwise comparison towards respondents' attributes
4.5	Table 4.5: Rejected Null Hypothesis for Problems in Current Construction Logistics Practices
4.6	Table 4.7: Rejected Null Hypothesis for the Perception towards Relevance of Construction Logistics Activities to AI Adoptions
4.7	Table 4.9: Rejected Null Hypothesis for Agreements Towards Statements Related to The Functions of Each AI Adoptions in Construction Logistics
4.8	Table 4.11: Rejected Null Hypothesis for Perception towards the Organisation's Plan for AI Adoption in Different Construction Logistics Activities
4.9	Table 4.13: Rejected Null Hypothesis for Perception Towards the Organisation's Plan with Different AI Adoptions in Construction Logistics

CHAPTER 4

DATA ANALYSIS AND DISCUSSION

4.1 Introduction

The results of the survey are reported and analysed in this chapter in order to obtain and infer the results for generalisation. In Section 4.2, the demographic information is introduced. The results of Shapiro-Wilk Test and normality test are shown in Section 4.3 and 4.4. Results of collected data about the problems of construction logistics in current practices, the perception towards the AI relevance to construction logistics activities, the agreements to the functions of AI applications, the organisation plan for AI adoption and the challenges of AI adoptions are reported in Section 4.5 to Section 4.11 respectively. Lastly, these findings are discussed and compared with literature review in Section 4.12.

4.2 Respondents' Background

A total of 154 sets of questionnaires are sent via social media for example Facebook, WhatsApp and also email. Table 4.1 summarises the details of respondents' background. More than half of the respondents are female (55.2%) while the highest number of respondents are working in contractor company (21.4%). Majority of the respondents have a role as executive in their company (29.9%) and 29.2 % of them have 3 to 5 years working experiences.

4.2.1 Response Rate

The questionnaires are mainly disseminated by using online survey. There are approximately 370 questionnaires were sent out online through Facebook, WhatsApp and also email to the targeted respondents who worked in contractor firms, subcontractor firms, specialist firms, supplier firms and logistics service provider firms between February 2021 and April 2021. Among these 370 questionnaires, only 154 responses were answered and duly received. Thus, the overall response rate in this research is about 41.6%.

Table 4.1: Respondents' Attributes (N=154)

Demographic Information	Categories	Frequency	Percentage (%)
Organisation Business Activities	Contractor	33	21.4
	Sub-contractor	30	19.5
	Supplier	30	19.5
	Specialist	30	19.5
	Logistics Services Provider	31	20.1
Job Position	Assistant	37	24.0
	Executive	46	29.9
	Manager/Project Manager	40	26.0
	Deputy Director/Director	31	20.1
Working Experience	Less than 2 years	38	24.7
	3 – 5 years	45	29.2
	6 – 10 years	30	19.5
	More than 10 years	41	26.6

Remark: N = Total number of respondents

4.3 Shapiro-Wilk W Test

Table 4.2 shows the result of normality test for three sections of this questionnaire. All of the significance of the three sections are smaller than 0.05, which indicate that these sections' construction is deviated from normal distribution.

Table 4.2: Significance of Shapiro-Wilk W Test

Sections	Significance (Sig.)
Section B (B1 to B4): AI Adoptions in Construction Logistics	0.000
Section C (C2 & C3): Problems in Current Construction Logistics Practices	0.000
Section D (D1): Challenges of AI Adoptions	0.000

4.4 Cronbach's Alpha Reliability Test

Table 4.3 shows the result of reliability test for three sections of this questionnaire. All of the Cronbach alpha value of the three sections are bigger than 0.7, which indicate that these sections' construction is internally consistent.

Table 4.3: Cronbach Alpha Value of Reliability Test

Sections	Cronbach alpha value
Section B (B1 to B4): AI Adoptions in Construction Logistics	0.727
Section C (C2 & C3): Problems in Current Construction Logistics Practices	0.825
Section D (D1): Challenges of AI Adoptions	0.700

4.5 Problems Faced in Current Construction Logistics Practices

The ranking of the problems faced in current construction logistics practices are reported in Table 4.4. The results show the problems faced in current construction logistics practices in descending order are lack of collaborations, cost overrun, worker safety problems, time overrun, road damage, noise pollution and air pollution.

Table 4.4: Ranking on Problems in Current Construction Logistics Practices

Problems in Current Construction Logistics Practices	Median	Frequency of Median	Rank
Lack of collaborations	5.00	91	1
Cost overrun	5.00	83	2
Worker safety problems	4.00	69	3
Time overrun	4.00	66	4
Road damage	4.00	62	5
Noise pollution	3.50	68	6
Air pollution	3.00	84	7

Remark: 1 = Never, 2 = Seldom, 3 = Sometimes, 4 = Frequently, 5 = Always

Majority of the respondents always faced problems related to lack of collaborations between parties and cost overrun in their current and previous project. Some of the respondents frequently face problems pertaining to worker safety problems, time overrun and roads damages. There are 68 respondents sometimes or frequently face noise pollution in their project. The air pollution problems sometimes are faced by 84 respondents in their current or past project.

The rejected null hypothesis related to problems faced in current construction logistics practices by conducting the Mann-Whitney test to compare different perception between different groups of respondents in Table 4.5.

Table 4.5: Rejected Null Hypothesis for Problems in Current Construction Logistics Practices

Rejected Null Hypothesis	Sig.
The problem in current construction practices is cost overrun and same between the group of “contractor” and “subcontractor”.	.039
The problem in current construction practices is time overrun and same between the group of “contractor” and “subcontractor”.	.011
The problem in current construction practices is lack of collaborations and same between the group of “contractor” and “subcontractor”.	.010
The problem in current construction practices is worker safety problems and same between the group of “contractor” and “supplier”.	.002
The problem in current construction practices is lack of collaborations and same between the group of “contractor” and “supplier”.	.000
The problem in current construction practices is lack of collaborations and same between the group of “contractor” and “specialist”.	.016
The problem in current construction practices is worker safety problems and same between the group of “contractor” and “logistics”.	.002
The problem in current construction practices is lack of collaborations and same between the group of “contractor” and “logistics”.	.001
The problem in current construction practices is cost overrun and same between the group of “subcontractor” and “supplier”.	.000
The problem in current construction practices is time overrun and same between the group of “subcontractor” and “supplier”.	.032
The problem in current construction practices is cost overrun and same between the group of “subcontractor” and “logistics”.	.027
The problem in current construction practices is time overrun and same between the group of “subcontractor” and “logistics”.	.033
The problem in current construction practices is cost overrun and same between the group of “assistant” and “executive”.	.002
The problem in current construction practices is time overrun and same between the group of “assistant” and “executive”.	.003
The problem in current construction practices is time overrun and same between the group of “assistant” and “manager or project manager”.	.030
The problem in current construction practices is worker safety problems and same between the group of “assistant” and “deputy director or director”.	.013
The problem in current construction practices is lack of collaborations and same between the group of “assistant” and “deputy director or director”.	.012

Table 4.5 (Continued)

The problem in current construction practices is cost overrun and same between the group of “executive” and “manager or project manager”.	.004
The problem in current construction practices is lack of collaborations and same between the group of “executive” and “manager or project manager”.	.025
The problem in current construction practices is worker safety problems and same between the group of “executive” and “deputy director or director”.	.043
The problem in current construction practices is lack of collaborations and same between the group of “executive” and “deputy director or director”.	.000
The problem in current construction practices is cost overrun and same between the group with “less than 2 years” and “3 to 5 years” working experience.	.000
The problem in current construction practices is time overrun and same between the group with “less than 2 years” and “3 to 5 years” working experience.	.005
The problem in current construction practices is roads damage and same between the group with “less than 2 years” and “3 to 5 years” working experience.	.003
The problem in current construction practices is roads damage and same between the group with “less than 2 years” and “more than 10 years” working experience.	.044
The problem in current construction practices is worker safety problems and same between the group with “less than 2 years” and “more than 10 years” working experience.	.007
The problem in current construction practices is worker safety problems and same between the group with “less than 2 years” and “more than 10 years” working experience.	.005
The problem in current construction practices is cost overrun and same between the group with “3 to 5 years” and “6 to 10 years” working experience.	.010
The problem in current construction practices is cost overrun and same between the group with “3 to 5 years” and “more than 10 years” working experience.	.013
The problem in current construction practices is worker safety problems and same between the group with “3 to 5 years” and “more than 10 years” working experience.	.031
The problem in current construction practices is lack of collaborations and same between the group with “3 to 5 years” and “more than 10 years” working experience.	.000
The problem in current construction practices is worker safety problems and same between the group with “6 to 10 years” and “more than 10 years” working experience.	.047

From the above significant test by using Mann-Whitney Test, the following pairs of respondents which are statistically significant different in the problems faced in current construction practices.

i) The group of subcontractor experienced

a) more cost overrun (mean rank = 36.10) in current construction logistics practices than the group of contractor (mean rank = 28.27).

b) more cost overrun (mean rank = 37.75) in current construction logistics practices than the group of supplier (mean rank = 23.25).

c) more cost overrun (mean rank = 35.25) in current construction logistics practices than the group of logistics (mean rank = 26.89).

d) more time overrun (mean rank = 37.50) in current construction logistics practices than the group of contractor (mean rank = 27.00).

e) more time overrun (mean rank = 34.70) in current construction logistics practices than the group of supplier (mean rank = 26.30).

f) more time overrun (mean rank = 35.27) in current construction logistics practices than the group of logistics (mean rank = 26.87).

g) more lack of collaborations (mean rank = 37.75) in current construction logistics practices than the group of contractor (mean rank = 26.77).

ii) The group of supplier experienced

a) more worker safety problem (mean rank = 38.75) in current construction logistics practices than the group of contractor (mean rank = 25.86).

b) more lack of collaborations (mean rank = 39.70) in current construction logistics practices than the group of contractor (mean rank = 25.00).

iii) The group of specialist experienced

a) more lack of collaboration (mean rank = 37.40) in current construction logistics practices than the group of contractor (mean rank = 27.09).

iv) The group of logistics experienced

a) more worker safety problem (mean rank = 39.35) in current construction logistics practices than the group of contractor (mean rank = 26.06).

b) more lack of collaboration (mean rank = 40.05) in current construction logistics practices than the group of contractor (mean rank = 25.41).

v) The group of executive experienced

a) more cost overrun (mean rank = 48.50) in current construction logistics practices than the group of assistant (mean rank = 33.92).

b) more time overrun (mean rank = 48.30) in current construction logistics practices than the group of assistant (mean rank = 34.16).

vi) The group of manager or project manager experienced

a) more time overrun (mean rank = 43.78) in current construction logistics practices than the group of assistant (mean rank = 33.84).

b) more cost overrun (mean rank = 49.71) in current construction logistics practices than the group of executive (mean rank = 39.36).

c) more lack of collaboration (mean rank = 49.30) in current construction logistics practices than the group of executive (mean rank = 38.46).

vii) The group of deputy director or director experienced

a) more worker safety problem (mean rank = 40.39) in current construction logistics practices than the group of assistant (mean rank = 29.57).

b) more worker safety problem (mean rank = 44.55) in current construction logistics practices than the group of executive (mean rank = 35.26).

c) more lack of collaboration (mean rank = 40.00) in current construction logistics practices than the group of assistant (mean rank = 29.89).

d) more lack of collaboration (mean rank = 48.63) in current construction logistics practices than the group of executive (mean rank = 32.51).

viii) The group with 3 to 5 years working experience experienced

a) more cost overrun (mean rank = 49.54) in current construction logistics practices than the group with less than 2 years working experience (mean rank = 33.07).
b) more time overrun (mean rank = 48.13) in current construction logistics practices than the group with less than 2 years working experience (mean rank = 34.74).
c) more roads damage (mean rank = 48.71) in current construction logistics practices than the group with less than 2 years working experience (mean rank = 34.05).

ix) The group with more than 10 years working experience experienced

a) more roads damage (mean rank = 44.61) in current construction logistics practices than the group with less than 2 years working experience (mean rank = 35.03).
b) more worker safety problems (mean rank = 45.99) in current construction logistics practices than the group with less than 2 years working experience (mean rank = 33.54).
c) more worker safety problems (mean rank = 48.82) in current construction logistics practices than the group with 3 to 5 years working experience (mean rank = 38.66).
d) more worker safety problems (mean rank = 39.65) in current construction logistics practices than the group with 6 to 10 years working experience (mean rank = 31.02).
e) more lack of collaboration (mean rank = 45.72) in current construction logistics practices than the group with less than 2 years working experience (mean rank = 33.83).
f) more lack of collaboration (mean rank = 52.15) in current construction logistics practices than the group with 3 to 5 working experience (mean rank = 35.62).

4.6 Perception towards the Relevance of Construction Logistics Activities with AI Adoptions

Table 4.6 shows the results of the extent of perception towards the relevance of construction logistics activities with AI adoptions. The table shows the median. frequency of median and their ranking.

Table 4.6: Ranking on Perception towards the Relevance of Construction Logistics Activities with AI Adoptions (N = 154)

Construction logistics activities	Median	Frequency of Median	Rank
Process of contracts and invoices	5.00	99	1
Further planning after prediction of delay	5.00	82	2
Planning and management of unloading and loading zones	4.00	81	3
On-site and off-site warehousing	4.00	78	4
Delivery and traffic management	4.00	66	5
Monitoring health and safety of site workers	4.00	57	6
Unloading and loading of materials	3.00	67	7

Remark: 1: Not at all, 2: Slight, 3: Moderately, 4: Very, 5: Extremely

Based on Table 4.6 above, majority of the respondents perceived that process of contract and invoices is extremely relevant to the AI adoptions. The second highest construction logistics activities that respondents perceived that extremely relevant to AI adoptions is further planning after prediction of delay. Moreover, there are 81 respondents perceived that planning and management of unloading and loading zones is the construction logistics activity that very relevant to AI adoptions. Some of the respondents perceived the rest of construction logistics activities are very relevant to AI adoptions are on-site and off-site warehousing, delivery and traffic management and monitoring health and safety of site workers. Unloading and loading of materials are perceived as moderately relevant to AI adoptions in construction logistics.

Mann-Whitney test are followed up to be conducted for perception towards the relevance of construction logistics activities with AI adoptions on all the attributes of the respondents and list of significant null hypothesis is shown in Table 4.7.

Table 4.7: Rejected Null Hypothesis for the Perception towards Relevance of Construction Logistics Activities to AI Adoptions

Rejected Null Hypothesis	Sig.
The perception on the relevance of process of contract and invoices with AI adoption is same between the group of “contractor” and “supplier”.	.046
The perception on the relevance of planning and management of loading and unloading zone with AI adoption is same between the group of “contractor” and “supplier”.	.021
The perception on the relevance of unloading and loading of materials with AI adoption is same between the group of “contractor” and “supplier”.	.037
The perception on the relevance of further planning of delay with AI adoption is same between the group of “contractor” and “supplier”.	.002
The perception on the relevance of process of contract and invoices with AI adoption is same between the group of “contractor” and “specialist”.	.004
The perception on the relevance of further planning of delay with AI adoption is same between the group of “contractor” and “specialist”.	.001
The perception on the relevance of further planning of delay with AI adoption is same between the group of “sub-contractor” and “supplier”.	.015
The perception on the relevance of planning and management of loading and unloading zone with AI adoption is same between the group of “supplier” and “specialist”.	.022
The perception on the relevance of unloading and loading of material with AI adoption is same between the group of “assistant” and “manager or project manager”.	.005
The perception on the relevance of monitoring health and safety of workers with AI adoption is same between the group of “assistant” and “manager or project manager”.	.006
The perception on the relevance of process of contract and invoices with AI adoption is same between the group of “assistant” and “deputy director or director”.	.016
The perception on the relevance of delivery and traffic management with AI adoption is same between the group of “assistant” and “deputy director or director”.	.045
The perception on the relevance of planning and management of loading and unloading zone with AI adoption is same between the group of “assistant” and “deputy director or director”.	.037
The perception on the relevance of unloading and loading of material with AI adoption is same between the group of “assistant” and “deputy director or director”.	.000
The perception on the relevance of monitoring health and safety of workers with AI adoption is same between the group of “assistant” and “deputy director or director”.	.008

Table 4.7 (Continued)

The perception on the relevance of unloading and loading of material with AI adoption is same between the group of "executive" and "manager or project manager".	.041
The perception on the relevance of unloading and loading of material with AI adoption is same between the group of "executive" and "deputy director or director".	.003
The perception on the relevance of further planning of delay with AI adoption is same between the group of "executive" and "deputy director or director".	.002
The perception on the relevance of delivery and traffic management with AI adoption is same between the group of "manager or project manager" and "deputy director or director".	.024
The perception on the relevance of process of contract and invoices with AI adoption is same between the group of "less than 2 years" and "3 to 5 years" working experience.	.035
The perception on the relevance of unloading and loading of material with AI adoption is same between the group of "less than 2 years" and "6 to 10 years" working experience.	.032
The perception on the relevance of process of contract and invoices with AI adoption is same between the group of "less than 2 years" and "more than 10 years" working experience.	.022
The perception on the relevance of unloading and loading of material with AI adoption is same between the group of "less than 2 years" and "more than 10 years" working experience.	.007
The perception on the relevance of monitoring health and safety of workers with AI adoption is same between the group of "less than 2 years" and "more than 10 years" working experience.	.002
The perception on the relevance of unloading and loading of material with AI adoption is same between the group of "3 to 5 years" and "more than 10 years" working experience.	.029
The perception on the relevance of monitoring health and safety of workers with AI adoption is same between the group of "3 to 5 years" and "more than 10 years" working experience.	.011
The perception on the relevance of further planning of delay with AI adoption is same between the group of "3 to 5 years" and "more than 10 years" working experience.	.002
The perception on the relevance of further planning of delay with AI adoption is same between the group of "6 to 10 years" and "more than 10 years" working experience.	.023

From the above significant test by using Mann-Whitney Test, the following pairs of respondents which are statistically significant different in perception towards the relevance of construction logistics activities to AI adoptions.

i) The group of supplier perceived

a) higher relevance of process of contract and invoices (mean rank = 36.33) with AI adoption than the group of contractor (mean rank = 27.53).
b) higher relevance of planning and management of loading and unloading zone (mean rank = 36.92) with AI adoption than the group of contractor (mean rank = 27.53).
c) higher relevance of unloading and loading of materials (mean rank = 36.55) with AI adoption than the group of contractor (mean rank = 27.86).
d) higher relevance of further planning after prediction of delay (mean rank = 38.82) with AI adoption than the group of contractor (mean rank = 25.8).
e) higher relevance of further planning after prediction of delay (mean rank = 35.43) with AI adoption than the group of sub-contractor (mean rank = 25.57).
f) higher relevance of planning and management of loading and unloading zone (mean rank = 35.33) with AI adoption than the group of specialist (mean rank = 25.67).

(ii) The group of specialist perceived

a) higher relevance of process of contract and invoices (mean rank = 36.08) with AI adoption than the group of contractor (mean rank = 28.29).
b) higher relevance of further planning after prediction of delay (mean rank = 39.55) with AI adoption than the group of contractor (mean rank = 25.88).

(iii) The group of assistant perceived

a) higher relevance of monitoring health and safety of workers (mean rank = 45.31) with AI adoption than the group of manager and project manager (mean rank = 32.18).
b) higher relevance of delivery and traffic management (mean rank = 38.58) with AI adoption than the group of deputy director of director (mean rank = 29.63).

(iv) The group of manager or project manager perceived

a) higher relevance of unloading and loading of materials (mean rank = 45.21) with AI adoption than the group of assistant (mean rank = 32.38).
b) higher relevance of monitoring health and safety of workers (mean rank = 45.31) with AI adoption than the group of assistant (mean rank = 32.18).
c) higher relevance of unloading and loading of material (mean rank = 47.35) with AI adoption than the group of executive (mean rank = 40.15).
d) higher relevance of delivery and traffic management (mean rank = 40.48) with AI adoption than the group of deputy director of director (mean rank = 30.23).

(v) The group of deputy director or director perceived

a) higher relevance of process of contract and invoices (mean rank = 39.77) with AI adoption than the group of assistant (mean rank = 30.08).
b) higher relevance of planning and management of loading and unloading zone (mean rank = 39.53) with AI adoption than the group of assistant (mean rank = 30.28).
c) higher relevance of unloading and loading of material (mean rank = 43.16) with AI adoption than the group of assistant (mean rank = 27.24).
d) higher relevance of monitoring health and safety of workers (mean rank = 40.97) with AI adoption than the group of assistant (mean rank = 29.08).
e) higher relevance of unloading and loading of material (mean rank = 47.27) with AI adoption than the group of executive (mean rank = 33.42).
f) higher relevance of further planning after prediction of delay (mean rank = 47.87) with AI adoption than the group of executive (mean rank = 33.02).

(vi) The group with 3 to 5 years working experience perceived

a) higher relevance of process of contract and invoices (mean rank = 46.61) with AI adoption than the group with less than 2 years working experience (mean rank = 36.78).

(vii) The group with 6 to 10 years working experience perceived

a) higher relevance of unloading and loading of material (mean rank = 39.80) with AI adoption than the group with less than 2 years working experience (mean rank = 30.32).

(viii) The group with more than 10 years working experience perceived

a) higher relevance of process of contract and invoices (mean rank = 44.9) with AI adoption than the group with less than 2 years working experience (mean rank = 34.71).

b) higher relevance of unloading and loading of material (mean rank = 46.16) with AI adoption than the group with less than 2 years working experience (mean rank = 33.36).

c) higher relevance of monitoring health and safety of workers (mean rank = 47.11) with AI adoption than the group with less than 2 years working experience (mean rank = 32.33).

d) higher relevance of unloading and loading of material (mean rank = 49.02) with AI adoption than the group with 3 to 5 years working experience (mean rank = 38.47).

e) higher relevance of monitoring health and safety of workers (mean rank = 50.05) with AI adoption than the group with 3 to 5 years working experience (mean rank = 37.53).

f) higher relevance of further planning after prediction of delay (mean rank = 51.41) with AI adoption than the group with 3 to 5 years working experience (mean rank = 36.29).

g) higher relevance of further planning after prediction of delay (mean rank = 40.10) with AI adoption than the group with 6 to 10 years working experience (mean rank = 30.40).

4.7 Agreements towards Statement Related to the Functions of each AI Adoptions in Construction Logistics

Table 4.8 shows the results of the extent of agreements towards statements related to the functions of each AI adoptions in construction logistics. The table shows the median, the frequency of median and their ranking.

Table 4.8: Ranking on Agreements Towards Statements Related to The Functions of Each AI Adoptions in Construction Logistics (N = 154)

Statements	Median	Frequency of Median	Rank
AGV is useful for repetitive transportation works in warehouse.	5.000	102	1
AI-based drone is useful for producing a detailed map of construction sites.	5.000	98	2
AI-back office is useful for detecting fraud by logistics service providers, classifying contractual clauses, managing and keeping all delivery information precisely.	4.000	101	3
AI-powered jobsite camera is useful for ensuring site security, workers' safety and analysing the flow of materials on site.	4.000	94	4
Autonomous truck is useful for repetitive delivery in factories, logistics centre or ports with high preciseness.	4.000	92	5
UAV and UGV are useful for tracking the inventories.	4.000	76	6
Predictive analytics is useful for reducing the uncertainty in logistics activities.	4.000	67	7
AI developer kits is useful for making AI robotics applications becomes more easier by making existing equipment autonomous.	4.000	62	8
Smart construction lift is useful to lift materials by determining running zones themselves efficiently.	3.000	80	9
Unmanned tower crane is useful to lift materials by voice recognition.	3.000	60	10

Remark: 1: Strongly Disagree, 2: Slight Disagree, 3: Moderately, 4: Slightly Agree, 5: Strongly Agree

Based on Table 4.8 above, majority of the respondents strongly agreed on “AGV is useful for repetitive transportation works in warehouse sites”. The second highest strongly agreed statement is “AI-based drone is useful for producing a detailed map of construction”. Moreover, there are 101 respondents slightly agreed “AI-back office is useful for detecting fraud by logistics service providers, classifying contractual clauses, managing and keeping all delivery information precisely”. The rest AI adoptions’ functions are only slightly agreed by respondents when more than 50% of respondents only moderately agreed on “Smart construction lift is useful to lift materials by determining running zones themselves efficiently”. There are 50 respondents only moderately agreed on “Unmanned tower crane is useful to lift materials by voice recognition”.

Table 4.9 shows the rejected null hypothesis related to extent of agreements towards statements related to the functions of each AI adoptions in construction logistics by conducting the Mann-Whitney test to compare different perception between different groups of respondents.

Table 4.9: Rejected Null Hypothesis for Agreements Towards Statements Related to The Functions of Each AI Adoptions in Construction Logistics

Rejected Null Hypothesis	Sig.
The agreements towards statements related to the functions of AGV is same between the group of “contractor” and “subcontractor”.	.001
The agreements towards statements related to the functions of AGV is same between the group of “contractor” and “supplier”.	.000
The agreements towards statements related to the functions of smart construction lift is same between the group of “contractor” and “supplier”.	.010
The agreements towards statements related to the functions of AGV is same between the group of “contractor” and “specialist”.	.001
The agreements towards statements related to the functions of AGV is same between the group of “contractor” and “logistics”.	.000
The agreements towards statements related to the functions of AI developer kits is same between the group of “contractor” and “logistics”.	.022
The agreements towards statements related to the functions of smart construction lift is same between the group of “subcontractor” and “supplier”.	.018
The agreements towards statements related to the functions of AI-powered jobsite cameras is same between the group of “subcontractor” and “supplier”.	.011

Table 4.9 (Continued)

The agreements towards statements related to the functions of predictive analytics is same between the group of “subcontractor” and “logistics”.	.038
The agreements towards statements related to the functions of AI developer kits is same between the group of “subcontractor” and “logistics”.	.018
The agreements towards statements related to the functions of AI developer kits is same between the group of “supplier” and “specialist”.	.036
The agreements towards statements related to the functions of autonomous vehicles is same between the group of “supplier” and “logistics”.	.029
The agreements towards statements related to the functions of autonomous vehicles is same between the group of “specialist” and “logistics”.	.046
The agreements towards statements related to the functions of AI developer kits is same between the group of “specialist” and “logistics”.	.003
The agreements towards statements related to the functions of AI-powered jobsite cameras is same between the group of “assistant” and “executive”.	.044
The agreements towards statements related to the functions of UAV and UGV is same between the group of “assistant” and “deputy director or director”.	.001
The agreements towards statements related to the functions of AI-powered jobsite cameras is same between the group of “assistant” and “deputy director or director”.	.005
The agreements towards statements related to the functions of AI-back office is same between the group of “assistant” and “deputy director or director”.	.032
The agreements towards statements related to the functions of smart construction lift is same between the group of “executive” and “manger or project manager”.	.032
The agreements towards statements related to the functions of UAV and UGV is same between the group of “executive” and “deputy director or director”.	.023
The agreements towards statements related to the functions of unmanned crane tower is same between the group of “executive” and “deputy director or director”.	.005
The agreements towards statements related to the functions of unmanned crane tower is same between the group of “manager or project manager” and “deputy director or director”.	.023
The agreements towards statements related to the functions of UAV and UGV is same between the group of “less than 2 years” and “6 to 10 years” working experience.	.034
The agreements towards statements related to the functions of UAV and UGV is same between the group of “less than 2 years” and “more than 10 years” working experience.	.009

Table 4.9 (Continued)

The agreements towards statements related to the functions of unmanned crane tower is same between the group of “less than 2 years” and “more than 10 years” working experience.	.007
The agreements towards statements related to the functions of smart construction lift is same between the group of “less than 2 years” and “more than 10 years” working experience.	.040
The agreements towards statements related to the functions of unmanned crane tower is same between the group of “3 to 5 years” and “more than 10 years” working experience.	.000
The agreements towards statements related to the functions of smart construction lift is same between the group of “3 to 5 years” and “more than 10 years” working experience.	.010
The agreements towards statements related to the functions of AGV is same between the group of “6 to 10 years” and “more than 10 years” working experience.	.034
The agreements towards statements related to the functions of unmanned crane tower is same between the group of “6 to 10 years” and “more than 10 years” working experience.	.001
The agreements towards statements related to the functions of predictive analytics is same between the group of “6 to 10 years” and “more than 10 years” working experience.	.010

From the above significant test by using Mann-Whitney Test, the following pairs of respondents which are statistically significant different in extent of agreements towards statements related to the functions of each AI adoptions in construction logistics.

i) The group of contractor agreed

a) more towards “Smart construction lift is useful to lift materials by determining running zones themselves efficiently” (mean rank = 37.06) than the group of supplier (mean rank = 26.43).

b) more towards “AI developer kits is useful for making AI robotics applications becomes more easier by making existing equipment autonomous” (mean rank = 37.23) than the group of logistics (mean rank = 27.47).

ii) The group of subcontractor agreed

a) more towards “AGV is useful for repetitive transportation works in warehouse” (mean rank = 39.30) than the group of contractor (mean rank = 25.36).
b) more towards “Smart construction lift is useful to lift materials by determining running zones themselves efficiently” (mean rank = 35.23) than the group of supplier (mean rank = 25.77).
c) more towards “AI developer kits is useful for making AI robotics applications becomes more easier by making existing equipment autonomous” (mean rank = 36.02) than the group of logistics (mean rank = 26.15).

iii) The group of supplier agreed

a) more towards “AGV is useful for repetitive transportation works in warehouse” (mean rank = 40.87) than the group of contractor (mean rank = 23.94).
b) more towards “AI-powered jobsite camera is useful for ensuring site security, workers' safety and analysing the flow of materials on site” (mean rank = 35.38) than the group of subcontractor (mean rank = 25.62).
c) more towards “Autonomous truck is useful for repetitive delivery in factories, logistics centre or ports with high preciseness” (mean rank = 35.18) than the group of logistics (mean rank = 26.95).

iv) The group of specialist agreed

a) more towards “AGV is useful for repetitive transportation works in warehouse” (mean rank = 39.57) than the group of contractor (mean rank = 25.12).
b) more towards “AI developer kits is useful for making AI robotics applications becomes more easier by making existing equipment autonomous” (mean rank = 34.90) than the group of supplier (mean rank = 26.10).

c) more towards “Autonomous truck is useful for repetitive delivery in factories, logistics centre or ports with high preciseness” (mean rank = 34.93) than the group of logistics (mean rank = 27.19).

d) more towards “AI developer kits is useful for making AI robotics applications becomes more easier by making existing equipment autonomous” (mean rank = 37.20) than the group of logistics (mean rank = 25.00).

v) The group of logistics agreed

a) more towards “AGV is useful for repetitive transportation works in warehouse” (mean rank = 42.21) than the group of contractor (mean rank = 23.38).

b) more towards “Predictive analytics is useful for reducing the uncertainty in logistics activities” (mean rank = 35.23) than the group of contractor (mean rank = 26.63).

vi) The group of assistant agreed

a) more towards “AI-powered jobsite camera is useful for ensuring site security, workers' safety and analysing the flow of materials on site” (mean rank = 47.12) than the group of executive (mean rank = 37.88).

b) more towards “UAV and UGV are useful for tracking the inventories” (mean rank = 41.12) than the group of deputy director or director (mean rank = 26.60).

c) more towards “AI-powered jobsite camera is useful for ensuring site security, workers' safety and analysing the flow of materials on site” (mean rank = 39.78) than the group of deputy director or director (mean rank = 28.19).

d) more towards “AI-back office is useful for detecting fraud by logistics service providers, classifying contractual clauses, managing and keeping all delivery information precisely” (mean rank = 38.54) than the group of deputy director or director (mean rank = 29.68).

vii) The group of executive agreed

a) more towards “Smart construction lift is useful to lift materials by determining running zones themselves efficiently” (mean rank = 48.43) than the group of manager or project manager (mean rank = 37.83).
b) more towards “UAV and UGV are useful for tracking the inventories” (mean rank = 43.17) than the group of deputy director or director (mean rank = 32.81).
c) more towards “Unmanned tower crane is useful to lift materials by voice recognition” (mean rank = 44.66) than the group of deputy director or director (mean rank = 30.60).

viii) The group of manager or project manager agreed

a) more towards “Unmanned tower crane is useful to lift materials by voice recognition” (mean rank = 40.60) than the group of deputy director or director (mean rank = 30.06).

ix) The group with less than 2 years working experience agreed

a) more towards “UAV and UGV are useful for tracking the inventories” (mean rank = 38.64) than the group with 6 to 10 years working experience (mean rank = 29.25).
b) more towards “UAV and UGV are useful for tracking the inventories” (mean rank = 46.26) than the group with more than 10 years working experience (mean rank = 34.20).
c) more towards “Unmanned tower crane is useful to lift materials by voice recognition” (mean rank = 46.87) than the group with more than 10 years working experience (mean rank = 33.63).
d) more towards “Smart construction lift is useful to lift materials by determining running zones themselves efficiently” (mean rank = 44.87) than the group more than 10 years working experience (mean rank = 35.49).

x) The group with 3 to 5 years working experience agreed

a) more towards "Unmanned tower crane is useful to lift materials by voice recognition" (mean rank = 52.69) than the group with more than 10 years working experience (mean rank = 33.41).

b) more towards "Smart construction lift is useful to lift materials by determining running zones themselves efficiently" (mean rank = 49.42) than the group with more than 10 years working experience (mean rank = 37.00).

xi) The group with 6 to 10 years working experience agreed

a) more towards "Unmanned tower crane is useful to lift materials by voice recognition" (mean rank = 44.73) than the group with more than 10 years working experience (mean rank = 29.61).

xii) The group with more than 10 years working experience agreed

a) more towards "AGV is useful for repetitive transportation works in warehouse" (mean rank = 39.80) than the group with 6 to 10 years working experience (mean rank = 30.80).

b) more towards "Predictive analytics is useful for reducing the uncertainty in logistics activities" (mean rank = 40.94) than the group with 6 to 10 years working experience (mean rank = 29.25).

4.8 Perception towards the Organisation's Plan for AI Adoption in Different Construction Logistics Activities

Table 4.10 shows the results of the extent of perception organisation's plan for AI adoption in different construction logistics activities. The table shows the median, the frequency of median and their ranking.

Table 4.10: Ranking on Perception towards the Organisation's Plan for AI Adoption in Different Construction Logistics Activities (N = 154)

Construction logistics activities	Median	Frequency of Median	Rank
Process of contracts and invoices	4.000	105	1
On-site and off-site warehousing	4.000	95	2
Further planning after prediction of delay	4.000	80	3
Monitoring health and safety of site workers	3.000	65	4
Planning and management of unloading and loading zones	3.000	37	5
Delivery and traffic management	2.000	63	6
Unloading and loading of materials	2.000	50	7

Remark: 1: Not plan at all, 2: Expect to use in future if able,
3: Expect to use in 5 years, 4: Expect to use in 3 years, 5: Using now

Based on Table 4.10 above, there are 105 respondents perceived their organisations are planning to adopt AI in process of contracts and invoices in the next 3 years. Moreover, AI in on-site and off-site warehousing are perceived to be adopted in 3 years by organisations of 95 respondents. Organisations of 80 respondents are perceived they will have AI application in further planning and prediction of delay in the future of 3 years. Furthermore, there are less than 50% of the respondents perceived their organisations will adopt AI in monitoring health and safety on site as well as planning and management of unloading and loading zones in the next 5 years. Lastly, there are 63 respondents, and 50 respondents perceived their organisations will only consider adopting AI in delivery and traffic management as well as unloading and loading of materials respectively in the future if able to have sufficient resources in terms of investment and technology.

The rejected null hypothesis related to perception on organisation's plan for AI adoption in different construction logistics activities are shown in Table 4.11 by conducting the Mann-Whitney test to compare different perception between different groups of respondents.

Table 4.11: Rejected Null Hypothesis for Perception towards the Organisation's Plan for AI Adoption in Different Construction Logistics Activities

Rejected Null Hypothesis	Sig.
The perception on the organisation's plan for AI adoption in process of contract and invoices is same between the group of "contractor" and "subcontractor".	.006
The perception on the organisation's plan for AI adoption in delivery and traffic management is same between the group of "contractor" and "subcontractor".	.007
The perception on the organisation's plan for AI adoption in planning and management of loading and unloading zone is same between the group of "contractor" and "subcontractor".	.007
The perception on the organisation's plan for AI adoption in unloading and loading of materials is same between the group of "contractor" and "subcontractor".	.014
The perception on the organisation's plan for AI adoption in process of contract and invoices is same between the group of "contractor" and "supplier".	.002
The perception on the organisation's plan for AI adoption in on-site and off-site warehousing is same between the group of "contractor" and "supplier".	.044
The perception on the organisation's plan for AI adoption in planning and management of loading and unloading zone is same between the group of "contractor" and "supplier".	.033
The perception on the organisation's plan for AI adoption in further planning after prediction of delay is same between the group of "contractor" and "supplier".	.009
The perception on the organisation's plan for AI adoption in process of contract and invoices is same between the group of "contractor" and "specialist".	.000
The perception on the organisation's plan for AI adoption in on-site and off-site warehousing is same between the group of "contractor" and "specialist".	.013
The perception on the organisation's plan for AI adoption in process of contract and invoices is same between the group of "contractor" and "logistics".	.000
The perception on the organisation's plan for AI adoption in on-site and off-site warehousing is same between the group of "contractor" and "logistics".	.000
The perception on the organisation's plan for AI adoption in delivery and traffic management is same between the group of "contractor" and "logistics".	.096
The perception on the organisation's plan for AI adoption in planning and management of loading and unloading zone is same between the group of "contractor" and "logistics".	.003
The perception on the organisation's plan for AI adoption in unloading and loading of materials is same between the group of "contractor" and "logistics".	.029

Table 4.11 (Continued)

The perception on the organisation's plan for AI adoption in further planning after prediction of delay is same between the group of "contractor" and "logistics".	.019
The perception on the organisation's plan for AI adoption in delivery and traffic management is same between the group of "subcontractor" and "supplier".	.068
The perception on the organisation's plan for AI adoption in further planning after prediction of delay is same between the group of "subcontractor" and "supplier".	.037
The perception on the organisation's plan for AI adoption in on-site and off-site warehousing is same between the group of "sub-contractor" and "logistics".	.036
The perception on the organisation's plan for AI adoption in on-site and off-site warehousing is same between the group of "supplier" and "logistics".	.076
The perception on the organisation's plan for AI adoption in delivery and traffic management is same between the group of "assistant" and "manager or project manager".	.033
The perception on the organisation's plan for AI adoption in planning and management of loading and unloading zone is same between the group of "assistant" and "manager or project manager".	.006
The perception on the organisation's plan for AI adoption in process of contract and invoices is same between the group of "assistant" and "deputy director or director".	.091
The perception on the organisation's plan for AI adoption in delivery and traffic management is same between the group of "assistant" and "deputy director or director".	.015
The perception on the organisation's plan for AI adoption in planning and management of loading and unloading zone is same between the group of "assistant" and "deputy director or director".	.006
The perception on the organisation's plan for AI adoption in process of contract and invoices is same between the group of "executive" and "deputy director or director".	.024
The perception on the organisation's plan for AI adoption in on-site and off-site warehousing is same between the group of "executive" and "deputy director or director".	.035
The perception on the organisation's plan for AI adoption in delivery and traffic management is same between the group with "less than 2 years" and "6 to 10 years" working experience.	.021
The perception on the organisation's plan for AI adoption in planning and management of loading and unloading zone is same between the group with "less than 2 years" and "6 to 10 years" working experience.	.004
The perception on the organisation's plan for AI adoption in on-site and off-site warehousing is same between the group with "less than 2 years" and "more than 10 years" working experience.	.023

Table 4.11 (Continued)

The perception on the organisation's plan for AI adoption in delivery and traffic management is same between the group with "less than 2 years" and "more than 10 years" working experience.	.002
The perception on the organisation's plan for AI adoption in planning and management of loading and unloading zone is same between the group with "less than 2 years" and "more than 10 years" working experience.	.004
The perception on the organisation's plan for AI adoption in loading and unloading of material is same between the group with "less than 2 years" and "more than 10 years" working experience.	.028
The perception on the organisation's plan for AI adoption in planning and management of loading and unloading zone is same between the group with "3 to 5 years" and "6 to 10 years" working experience.	.042
The perception on the organisation's plan for AI adoption in process of contract and invoices is same between the group with "3 to 5 years" and "more than 10 years" working experience.	.027
The perception on the organisation's plan for AI adoption in on-site and off-site warehousing is same between the group with "3 to 5 years" and "more than 10 years" working experience.	.007
The perception on the organisation's plan for AI adoption in delivery and traffic management is same between the group with "3 to 5 years" and "more than 10 years" working experience.	.025
The perception on the organisation's plan for AI adoption in process of contract and invoices is same between the group with "6 to 10 years" and "more than 10 years" working experience.	.090
The perception on the organisation's plan for AI adoption in on-site and off-site warehousing is same between the group with "6 to 10 years" and "more than 10 years" working experience.	.002

From the above significant test by using Mann-Whitney Test, the following pairs of respondents which are statistically significant different in the perception on organisation's plan for AI adoption in different construction logistics activities.

i) The group of contractor perceived
   a) higher AI adoption in delivery and traffic management (mean rank = 36.64) in their organisation's plan than the group of sub-contractor (mean rank = 26.90).

b) higher AI adoption in planning and management of loading and unloading zone (mean rank = 37.76) in their organisation's plan than the group of sub-contractor (mean rank = 25.67).
c) higher AI adoption in unloading and loading of material (mean rank = 37.23) in their organisation's plan than the group of sub-contractor (mean rank = 26.25).
d) higher AI adoption in planning and management of loading and unloading zone (mean rank = 36.41) in their organisation's plan than the group of supplier (mean rank = 27.15).
e) higher AI adoption in delivery and traffic management (mean rank = 35.97) in their organisation's plan than the group of contractor (mean rank = 28.81).
f) higher AI adoption in planning and management of loading and unloading zone (mean rank = 38.89) in their organisation's plan than the group of logistics (mean rank = 25.69).
g) higher AI adoption in unloading and loading of material (mean rank = 37.24) in their organisation's plan than the group of logistics (mean rank = 27.45).

ii) The group of sub-contractor perceived

a) higher AI adoption in process of contract and invoices (mean rank = 37.93) in their organisation's plan than the group of contractor (mean rank = 26.61).

iii) The group of supplier perceived

a) higher AI adoption in process of contract and invoices (mean rank = 38.83) in their organisation's plan than the group of contractor (mean rank = 25.79).
b) higher AI adoption in on-site and off-site warehousing (mean rank = 36.42) in their organisation's plan than the group of contractor (mean rank = 27.98).

c) higher AI adoption in future planning after prediction of delay (mean rank = 37.87) in their organisation's plan than the group of contractor (mean rank = 26.67).
d) higher AI adoption in delivery and traffic management (mean rank = 34.33) in their organisation's plan than the group of subcontractor (mean rank = 26.67).
e) higher AI adoption in future planning after prediction of delay (mean rank = 33.30) in their organisation's plan than the group of subcontractor (mean rank = 27.70).

iv) The group of specialist perceived
a) higher AI adoption in process of contract and invoices (mean rank = 39.60) in their organisation's plan than the group of contractor (mean rank = 25.09).
b) higher AI adoption in on-site and off-site warehousing (mean rank = 37.47) in their organisation's plan than the group of contractor (mean rank = 27.03).

v) The group of logistics perceived
a) higher AI adoption in process of contract and invoices (mean rank = 40.81) in their organisation's plan than the group of contractor (mean rank = 24.70).
b) higher AI adoption in on-site and off-site warehousing (mean rank = 40.31) in their organisation's plan than the group of contractor (mean rank = 25.17).
c) higher AI adoption in future planning after prediction of delay (mean rank = 37.85) in their organisation's plan than the group of contractor (mean rank = 27.47).
d) higher AI adoption in on-site and off-site warehousing (mean rank = 34.95) in their organisation's plan than the group of subcontractor (mean rank = 26.92).

e) higher AI adoption in on-site and off-site warehousing (mean rank = 34.13) in their organisation’s plan than the group of supplier (mean rank = 27.77).

vi) The group of assistant perceived

a) higher AI adoption in delivery and traffic management (mean rank = 44.32) in their organisation’s plan than the group of manager or project manager (mean rank = 34.08).
b) higher AI adoption in planning and management of loading and unloading zone (mean rank = 45.97) in their organisation’s plan than the group of manager or project manager (mean rank = 32.55).
c) higher AI adoption in delivery and traffic management (mean rank = 39.53) in their organisation’s plan than the group of deputy director or director (mean rank = 28.50).
d) higher AI adoption in planning and management of loading and unloading zone (mean rank = 40.16) in their organisation’s plan than the group of deputy director or director (mean rank = 27.74).

vii) The group of deputy director or director perceived

a) higher AI adoption in process of contract and invoices (mean rank = 37.71) in their organisation’s plan than the group of assistant (mean rank = 31.81).
b) higher AI adoption in on-site and off-site warehousing (mean rank = 44.68) in their organisation’s plan than the group of executive (mean rank =35.17).

viii) The group with less than 2 years working experience perceived

a) higher AI adoption in delivery and traffic management (mean rank = 39.16) in their organisation’s plan than the group with 6 to 10 years working experience (mean rank = 28.60).
b) higher AI adoption in planning and management of loading and unloading zone (mean rank = 40.36) in their organisation’s plan than the group with 6 to 10 years working experience (mean rank = 27.08).

c) higher AI adoption in delivery and traffic management (mean rank = 47.84) in their organisation's plan than the group with more than 10 years working experience (mean rank = 32.73).
d) higher AI adoption in planning and management of loading and unloading zone (mean rank = 47.26) in their organisation's plan than the group with more than 10 years working experience (mean rank = 33.27).
e) higher AI adoption in loading and unloading of material (mean rank = 45.63) in their organisation's plan than the group with more than 10 years working experience (mean rank = 34.78).

ix) The group with 3 to 5 years working experience perceived

a) higher AI adoption in planning and management of loading and unloading zone (mean rank = 41.98) in their organisation's plan than the group with 6 to 10 years working experience (mean rank = 32.03).
b) higher AI adoption in delivery and traffic management (mean rank = 48.86) in their organisation's plan than the group with more than 10 years working experience (mean rank = 37.62).

x) The group with more than 10 years working experience perceived

a) higher AI adoption in on-site and off-site warehousing (mean rank = 44.67) in their organisation's plan than the group with less than 2 years working experience (mean rank =34.96).
b) higher AI adoption in process of contract and invoices (mean rank = 48.54) in their organisation's plan than the group with 3 to 5 years working experience (mean rank = 38.91).
c) higher AI adoption in on-site and off-site warehousing (mean rank = 50.07) in their organisation's plan than the group with 3 to 5 years working experience (mean rank =37.51).
d) higher AI adoption in process of contract and invoices (mean rank = 38.95) in their organisation's plan than the group with 6 to 10 years working experience (mean rank = 31.97).

e) higher AI adoption in on-site and off-site warehousing (mean rank = 41.84) in their organisation's plan than the group with 6 to 10 years working experience (mean rank =28.02).

4.9 Perception towards the Organisation's Plan with Different AI Adoptions in Construction Logistics

Table 4.12 shows the results of the perception towards the organisation's plan with different AI adoption in construction logistics. The table also shows the median, the frequency of median and its ranking,

Table 4.12: Ranking on perception towards the organisation's plan with different AI adoptions in construction logistics (N = 154)

AI adoptions in construction logistics activities	Median	Frequency of Median	Rank
UAV and UGV	4.000	104	1
AGV	4.000	103	2
Predictive analytics	4.000	88	3
AI-based drone	4.000	78	4
AI-powered jobsite camera	3.000	66	5
AI-back office	3.000	55	6
Smart construction lift	2.000	42	7
Autonomous truck	2.000	61	8
Unmanned tower crane	2.000	48	9
AI developer kits	2.000	30	10

Remark: 1: Not plan at all, 2: Expect to use in future if able,
3: Expect to use in 5 years, 4: Expect to use in 3 years, 5: Using now

Based on Table 4.12, majority of the respondents perceived their organisations are planning to have UAV and UGV, AGV, predictive analytics and AI-based drones in the next 3 years. There are 55 respondents, and 42 respondents perceived their organisations will adopt AI-powered jobsite camera and AI-back office in the next 5 years respectively. The rest of AI adoptions such as smart construction lift, autonomous truck, unmanned tower crane and AI developer kits are perceived by some of the respondents that their organisations will adopt these AI application in the future if able to obtain sufficient resources in terms of technology and investments.

Table 4.13 shows the rejected null hypothesis related to perception organisation's plan for AI adoption in different construction logistics activities by conducting the Mann-Whitney test to compare different perception between different groups of respondents.

Table 4.13: Rejected Null Hypothesis for Perception Towards the Organisation's Plan with Different AI Adoptions in Construction Logistics

Rejected Null Hypothesis	Sig.
The perception on the organisation's plan for adoption of AGV is same between the group of "contractor" and "subcontractor".	.010
The perception on the organisation's plan for adoption of UAV and UGV is same between the group of "contractor" and "subcontractor".	.009
The perception on the organisation's plan for adoption of autonomous vehicles is same between the group of "contractor" and "subcontractor".	.062
The perception on the organisation's plan for adoption of smart construction lift is same between the group of "contractor" and "subcontractor".	.018
The perception on the organisation's plan for adoption of predictive analytics same between the group of "contractor" and "subcontractor".	.015
The perception on the organisation's plan for adoption of AGV is same between the group of "contractor" and "supplier".	.000
The perception on the organisation's plan for adoption of UAV and UGV is same between the group of "contractor" and "supplier".	.000
The perception on the organisation's plan for adoption of autonomous vehicles is same between the group of "contractor" and "supplier".	.074
The perception on the organisation's plan for adoption of unmanned crane tower is same between the group of "contractor" and "supplier".	.001
The perception on the organisation's plan for adoption of smart construction lift is same between the group of "contractor" and "supplier".	.001
The perception on the organisation's plan for adoption of AI-powered jobsite cameras is same between the group of "contractor" and "supplier".	.010
The perception on the organisation's plan for adoption of AI-back office is same between the group of "contractor" and "supplier".	.017
The perception on the organisation's plan for adoption of predictive analytics is same between the group of "contractor" and "supplier".	.000
The perception on the organisation's plan for adoption of AGV is same between the group of "contractor" and "specialist".	.010
The perception on the organisation's plan for adoption of UAV and UGV is same between the group of "contractor" and "specialist".	.025
The perception on the organisation's plan for adoption of unmanned crane tower is same between the group of "contractor" and "specialist".	.015

Table 4.13 (Continued)

The perception on the organisation's plan for adoption of smart construction lift is same between the group of "contractor" and "specialist".	.022
The perception on the organisation's plan for adoption of AI-back office is same between the group of "contractor" and "specialist".	.080
The perception on the organisation's plan for adoption of predictive analytics is same between the group of "contractor" and "specialist".	.008
The perception on the organisation's plan for adoption of AGV is same between the group of "contractor" and "logistics".	.000
The perception on the organisation's plan for adoption of UAV and UGV is same between the group of "contractor" and "logistics".	.006
The perception on the organisation's plan for adoption of autonomous vehicles is same between the group of "contractor" and "logistics".	.041
The perception on the organisation's plan for adoption of unmanned crane tower is same between the group of "contractor" and "logistics".	.000
The perception on the organisation's plan for adoption of smart construction lift is same between the group of "contractor" and "logistics".	.000
The perception on the organisation's plan for adoption of AI-powered jobsite cameras is same between the group of "contractor" and "logistics".	.001
The perception on the organisation's plan for adoption of predictive analytics is same between the group of "contractor" and "logistics".	.004
The perception on the organisation's plan for adoption of predictive analytics is same between the group of "subcontractor" and "supplier".	.033
The perception on the organisation's plan for adoption of smart construction lift is same between the group of "subcontractor" and "logistics".	.019
The perception on the organisation's plan for adoption of AI-powered jobsite cameras is same between the group of "subcontractor" and "logistics".	.020
The perception on the organisation's plan for adoption of smart construction lift is same between the group of "specialist" and "logistics".	.019
The perception on the organisation's plan for adoption of AI-powered jobsite cameras is same between the group of "specialist" and "logistics".	.048
The perception on the organisation's plan for adoption of UAV and UGV is same between the group of "assistant" and "executive".	.048

Table 4.13 (Continued)

The perception on the organisation's plan for adoption of UAV and UGV is same between the group of "assistant" and "manager or project manager".	.006
The perception on the organisation's plan for adoption of unmanned crane tower is same between the group of "assistant" and "manager or project manager".	.013
The perception on the organisation's plan for adoption of smart construction lift is same between the group of "assistant" and "manager or project manager".	.001
The perception on the organisation's plan for adoption of AI-powered jobsite cameras is same between the group of "assistant" and "manager or project manager".	.003
The perception on the organisation's plan for adoption of AI-based drone is same between the group of "assistant" and "manager or project manager".	.003
The perception on the organisation's plan for adoption of UAV and UGV is same between the group of "assistant" and "deputy director or director".	.026
The perception on the organisation's plan for adoption of smart construction lift is same between the group of "assistant" and "deputy director or director".	.009
The perception on the organisation's plan for adoption of predictive analytics same between the group of "assistant" and "deputy director or director".	.025
The perception on the organisation's plan for adoption of unmanned crane tower is same between the group of "executive" and "manager or project manager".	.008
The perception on the organisation's plan for adoption of smart construction lift is same between the group of "executive" and "manager or project manager".	.001
The perception on the organisation's plan for adoption of AI-powered jobsite cameras is same between the group of "executive" and "manager or project manager".	.005
The perception on the organisation's plan for adoption of AI-based drone is same between the group of "executive" and "manager or project manager".	.006
The perception on the organisation's plan for adoption of smart construction lift is same between the group of "executive" and "deputy director or director".	.016
The perception on the organisation's plan for adoption of AI-based drone is same between the group of "executive" and "deputy director or director".	.036
The perception on the organisation's plan for adoption of predictive analytics is same between the group of "executive" and "deputy director or director".	.002
The perception on the organisation's plan for adoption of AI-based drone is same between the group of "manager or project manager" and "deputy director or director".	.000

Table 4.13 (Continued)

The perception on the organisation's plan for adoption of predictive analytics is same between the group of "manager or project manager" and "deputy director or director".	.039
The perception on the organisation's plan for adoption of AGV is same between the group with "less than 2 years" and "more than 10 years" working experience.	.016
The perception on the organisation's plan for adoption of UAV and UGV is same between the group with "less than 2 years" and "more than 10 years" working experience.	.000
The perception on the organisation's plan for adoption of unmanned tower crane is same between the group with "less than 2 years" and "more than 10 years" working experience.	.000
The perception on the organisation's plan for adoption of smart construction lift is same between the group with "less than 2 years" and "more than 10 years" working experience.	.000
The perception on the organisation's plan for adoption of AI-powered jobsite cameras is same between the group with "less than 2 years" and "more than 10 years" working experience.	.001
The perception on the organisation's plan for adoption of predictive analytics is same between the group with "less than 2 years" and "more than 10 years" working experience.	.080
The perception on the organisation's plan for adoption of AI developer kits is same between the group with "less than 2 years" and "more than 10 years" working experience.	.011
The perception on the organisation's plan for adoption of smart construction lift is same between the group with "3 to 5 years" and "6 to 10 years" working experience.	.032
The perception on the organisation's plan for adoption of AGV is same between the group with "3 to 5 years" and "more than 10 years" working experience.	.009
The perception on the organisation's plan for adoption of UAV and UGV is same between the group with "3 to 5 years" and "more than 10 years" working experience.	.007
The perception on the organisation's plan for adoption of unmanned crane tower is same between the group with "3 to 5 years" and "more than 10 years" working experience.	.000
The perception on the organisation's plan for adoption of smart construction lift is same between the group with "3 to 5 years" and "more than 10 years" working experience.	.000
The perception on the organisation's plan for adoption of AI-powered jobsite cameras is same between the group with "3 to 5 years" and "more than 10 years" working experience.	.000
The perception on the organisation's plan for adoption of predictive analytics is same between the group with "3 to 5 years" and "more than 10 years" working experience.	.011
The perception on the organisation's plan for adoption of AI developer kits is same between the group with "3 to 5 years" and "more than 10 years" working experience.	.004

Table 4.13 (Continued)

The perception on the organisation's plan for adoption of AGV is same between the group with "6 to 10 years" and "more than 10 years" working experience.	.016
The perception on the organisation's plan for adoption of UAV and UGV is same between the group with "6 to 10 years" and "more than 10 years" working experience.	.005
The perception on the organisation's plan for adoption of unmanned crane tower is same between the group with "6 to 10 years" and "more than 10 years" working experience.	.040
The perception on the organisation's plan for adoption of smart construction lift is same between the group with "6 to 10 years" and "more than 10 years" working experience.	.075
The perception on the organisation's plan for adoption of AI-powered jobsite cameras is same between the group with "6 to 10 years" and "more than 10 years" working experience.	.045

From the above significant test by using Mann-Whitney Test, the following pairs of respondents which are statistically significant different in extent of perception organisation's plan for AI adoption in different construction logistics activities.

i) The group of contractor perceived
   a) higher adoption of autonomous vehicles (mean rank = 35.86) in their organisation's plan than the group of subcontractor (mean rank = 27.75).
   b) higher adoption of smart construction lift (mean rank = 37.03) in their organisation's plan than the group of subcontractor (mean rank = 26.47).
   c) higher adoption of autonomous vehicles (mean rank = 35.59) in their organisation's plan than the group of supplier (mean rank = 28.05).
   d) higher adoption of unmanned tower crane (mean rank = 38.95) in their organisation's plan than the group of supplier (mean rank = 24.35).
   e) higher adoption of smart construction lift (mean rank = 39.12) in their organisation's plan than the group of supplier (mean rank = 24.17).
   f) higher adoption of AI-powered jobsite cameras (mean rank = 37.32) in their organisation's plan than the group of supplier (mean rank = 26.15).

g) higher adoption of unmanned tower crane (mean rank = 37.09) in their organisation’s plan than the group of specialist (mean rank = 26.40).
h) higher adoption of smart construction lift (mean rank = 36.88) in their organisation’s plan than the group of specialist (mean rank = 26.63).
i) higher adoption of autonomous vehicles (mean rank = 36.74) in their organisation’s plan than the group of logistics (mean rank = 27.98).
j) higher adoption of unmanned tower crane (mean rank = 40.32) in their organisation’s plan than the group of logistics (mean rank = 24.18).
k) higher adoption of smart construction lift (mean rank = 41.26) in their organisation’s plan than the group of logistics (mean rank = 23.18).
l) higher adoption of AI-powered jobsite cameras (mean rank = 39.33) in their organisation’s plan than the group of logistics (mean rank = 25.23).

ii) The group of subcontractor perceived
a) higher adoption of AGV (mean rank = 37.73) in their organisation’s plan than the group of contractor (mean rank = 26.79).
b) higher adoption of UAV and UGV (mean rank = 37.87) in their organisation’s plan than the group of contractor (mean rank = 26.67).
c) higher adoption of predictive analytics (mean rank = 37.60) in their organisation’s plan than the group of contractor (mean rank = 26.91).
d) higher adoption of smart construction lift (mean rank = 36.05) in their organisation’s plan than the group of logistics (mean rank = 26.11).
e) higher adoption of AI-powered jobsite cameras (mean rank = 35.93) in their organisation’s plan than the group of logistics (mean rank = 26.23).

iii) The group of supplier perceived
a) higher adoption of AGV (mean rank = 40.03) in their organisation’s plan than the group of contractor (mean rank = 24.70).
b) higher adoption of UAV and UGV (mean rank = 40.35) in their organisation’s plan than the group of contractor (mean rank = 24.41).
c) higher adoption of AI-back office (mean rank = 37.45) in their organisation’s plan than the group of contractor (mean rank = 27.05).

d) higher adoption of predictive analytics (mean rank = 41.02) in their organisation's plan than the group of contractor (mean rank = 23.80).

e) higher adoption of predictive analytics (mean rank = 34.23) in their organisation's plan than the group of subcontractor (mean rank = 26.77).

iv) The group of specialist perceived

a) higher adoption of AGV (mean rank = 37.73) in their organisation's plan than the group of contractor (mean rank = 26.79).

b) higher adoption of UAV and UGV (mean rank = 36.90) in their organisation's plan than the group of contractor (mean rank = 27.55).

c) higher adoption of AI back office (mean rank = 36.02) in their organisation's plan than the group of contractor (mean rank = 28.35).

d) higher adoption of predictive analytics (mean rank = 38.17) in their organisation's plan than the group of contractor (mean rank = 26.39).

e) higher adoption of smart construction lift (mean rank = 36.05) in their organisation's plan than the group of logistics (mean rank = 26.11).

f) higher adoption of AI-powered jobsite cameras (mean rank = 35.28) in their organisation's plan than the group of logistics (mean rank = 26.85).

v) The group of logistics perceived

a) higher adoption of AGV (mean rank = 40.69) in their organisation's plan than the group of contractor (mean rank = 24.80).

b) higher adoption of UAV and UGV (mean rank = 38.60) in their organisation's plan than the group of contractor (mean rank = 26.77).

c) higher adoption of predictive analytics (mean rank = 39.13) in their organisation's plan than the group of contractor (mean rank = 26.27).

vi) The group of assistant perceived

a) higher adoption of unmanned tower crane (mean rank = 45.24) in their organisation's plan than the group of manager or project manager (mean rank = 33.23).

b) higher adoption of smart construction lift (mean rank = 47.54) in their organisation's plan than the group of manager or project manager (mean rank = 31.10).

c) higher adoption of AI-powered jobsite cameras (mean rank = 46.34) in their organisation's plan than the group of manager or project manager (mean rank = 32.21).

d) higher adoption of AI-based drone (mean rank = 46.32) in their organisation's plan than the group of manager or project manager (mean rank = 32.23).

e) higher adoption of smart construction lift (mean rank = 39.97) in their organisation's plan than the group of deputy director or director (mean rank = 27.97).

vii) The group of executive perceived

a) higher adoption of UAV and UGV (mean rank = 46.09) in their organisation's plan than the group of assistant (mean rank = 36.92).

b) higher adoption of unmanned tower crane (mean rank = 49.80) in their organisation's plan than the group of manager or project manager (mean rank = 36.25).

c) higher adoption of smart construction lift (mean rank = 51.20) in their organisation's plan than the group of manager or project manager (mean rank = 34.65).

d) higher adoption of AI-powered jobsite cameras (mean rank = 51.14) in their organisation's plan than the group of manager or project manager (mean rank = 35.86).

e) higher adoption of AI-based drone (mean rank = 50.00) in their organisation's plan than the group of manager or project manager (mean rank = 36.03).

f) higher adoption of smart construction lift (mean rank = 43.84) in their organisation's plan than the group of deputy director or director (mean rank = 31.82).

viii) The group of manager or project manager perceived

a) higher adoption of UAV and UGV (mean rank = 44.95) in their organisation’s plan than the group of assistant (mean rank = 32.57).

ix) The group of deputy director or director perceived

a) higher adoption of UAV and UGV (mean rank = 39.39) in their organisation’s plan than the group of assistant (mean rank = 30.41).
b) higher adoption of predictive analytics (mean rank = 39.71) in their organisation’s plan than the group of assistant (mean rank = 30.14).
c) higher adoption of AI-based drone (mean rank = 44.79) in their organisation’s plan than the group of executive (mean rank = 35.10).
d) higher adoption of predictive analytics (mean rank = 47.60) in their organisation’s plan than the group of executive (mean rank = 33.21).
e) higher adoption of AI-based drone (mean rank = 46.69) in their organisation’s plan than the group of manager or project manager (mean rank = 27.71).
f) higher adoption of AI-based drone (mean rank = 41.15) in their organisation’s plan than the group of manager or project manager (mean rank = 32.01).

x) The group with less than 2 years working experience perceived

a) higher adoption of unmanned tower crane (mean rank = 49.25) in their organisation’s plan than the group with more than 10 years working experience (mean rank = 31.43).
b) higher adoption of smart construction lift (mean rank = 49.83) in their organisation’s plan than the group with more than 10 years working experience (mean rank = 30.89).
c) higher adoption of AI-powered jobsite cameras (mean rank = 48.55) in their organisation’s plan than the group with more than 10 years working experience (mean rank = 32.07).
d) higher adoption of AI developer kits (mean rank = 46.58) in their organisation’s plan than the group with more than 10 years working experience (mean rank = 33.90).

xi) The group with 3 to 5 years working experience perceived

a) higher adoption of smart construction lift (mean rank = 42.27) in their organisation's plan than the group with 6 to 10 years working experience (mean rank = 31.60).
b) higher adoption of unmanned tower crane (mean rank = 53.01) in their organisation's plan than the group with more than 10 years working experience (mean rank = 33.06).
c) higher adoption of smart construction lift (mean rank = 56.07) in their organisation's plan than the group with more than 10 years working experience (mean rank = 29.71).
d) higher adoption of AI-powered jobsite cameras (mean rank = 52.79) in their organisation's plan than the group with more than 10 years working experience (mean rank = 33.30).
e) higher adoption of AI developer kits (mean rank = 50.51) in their organisation's plan than the group with more than 10 years working experience (mean rank = 35.80).

xii) The group with 6 to 10 years working experience perceived

a) higher adoption of unmanned tower crane (mean rank = 41.27) in their organisation's plan than the group with more than 10 years working experience (mean rank = 32.15).
b) higher adoption of smart construction lift (mean rank = 40.47) in their organisation's plan than the group with more than 10 years working experience (mean rank = 32.73).
c) higher adoption of AI-powered jobsite cameras (mean rank = 41.40) in their organisation's plan than the group with more than 10 years working experience (mean rank = 32.05).

xiii) The group with more than 10 years working experience perceived

a) higher adoption of AGV (mean rank = 44.63) in their organisation's plan than the group with less than 2 years working experience (mean rank = 35.00).

b) higher adoption of UAG and UGV (mean rank = 47.80) in their organisation's plan than the group with less than 2 years working experience (mean rank = 31.58).

c) higher adoption of predictive analytics (mean rank = 43.90) in their organisation's plan than the group with less than 2 years working experience (mean rank = 35.79).

d) higher adoption of AGV (mean rank = 49.28) in their organisation's plan than the group with 3 to 5 years working experience (mean rank = 38.23).

e) higher adoption of UAV and UGV (mean rank = 49.65) in their organisation's plan than the group with 3 to 5 years working experience (mean rank = 37.90).

f) higher adoption of predictive analytics (mean rank = 50.04) in their organisation's plan than the group with 3 to 5 years working experience (mean rank = 37.54).

g) higher adoption of AGV (mean rank = 40.06) in their organisation's plan than the group with 6 to 10 years working experience (mean rank = 30.45).

h) higher adoption of UAV and UGV (mean rank = 41.06) in their organisation's plan than the group with 6 to 10 years working experience (mean rank = 29.08).

4.10 Agreement on Benefits of Logistics 4.0 in Construction Logistics

The results of the agreement on benefits of Logistics 4.0 in construction logistics are shown in Table 4.14. The table also shows the median, the frequency of median and its ranking.

Table 4.14: Ranking on Agreement on Benefits of Logistics 4.0 in Construction Logistics

Benefits of Logistics 4.0 in Construction Logistics	Median	Frequency of Median	Rank
Improve productivity	5.00	108	1
Improve transparency and flexibility	5.00	88	2
Ensure higher safety	4.00	85	3
Improve efficiency and effectiveness	4.00	75	4
Save cost	4.00	70	5
Increase revenue	3.00	84	7
Environmentally friendly	3.00	71	6

Remark: 1 = Not at all, 2 = Slight, 3 = Moderately, 4 = Very, 5 = Extremely

Based on Table 4.14, majority of the respondents extremely agree that Logistics 4.0 can improve the productivity as well as transparency and flexibility of construction logistics activities. There are 85, 75 and 70 respondents very agree that Logistics 4.0 can ensure higher safety, improve efficiency and effectiveness as well as save cost respectively. There are 71 respondents only moderately agree that Logistics 4.0 can increase revenue whereas 71 of the respondents moderately agree that Logistics 4.0 are environmentally friendly.

4.11 Perception on Factor Undermining AI Adoption in Construction Logistics

The results of the perception on factor undermining AI adoption in construction logistics are shown in Table 4.15. The table also shows the median, the frequency of median and its ranking.

Table 4.15: Ranking on Factor Undermining AI Adoption in Construction Logistics

Factor Undermining AI Adoption in Construction Logistics	Median	Frequency of Median	Rank
Lack of leaders’ commitment	5.00	89	1
Lack of employees’ commitment	5.00	85	2
Change of working culture	4.00	100	3
Privacy concerns	4.00	87	4
Algorithm aversion	4.00	50	5
Environmentally friendly	3.00	71	6

Remark: 1 = Strongly disagree, 2 = Slightly disagree, 3 = Uncertain, 4 = Slightly agree, 5 = Strongly agree

Based on Table 4.15, majority of the respondents strongly agree that Logistics 4.0 can improve the productivity as well as transparency and flexibility of construction logistics activities. There are 85, 75 and 70 respondents slightly agree that Logistics 4.0 can ensure higher safety, improve efficiency and effectiveness as well as save cost respectively. There are 71 respondents are uncertain about Logistics 4.0 can increase revenue whereas 71 of the respondents are uncertain that Logistics 4.0 are environmentally friendly.

4.12 Discussion

The discussion is revealed based on the results reported in the previous sections. In the following section, the findings are compared with literature reviewed whenever relevant.

4.12.1 Problems in Current Construction Logistics Practices

The top problem always faced by respondents in current construction logistics practices is lack of collaboration (Table 4.4). This finding is concurrent with the finding of research by Tsaxiri (2018) where “poor collaborations and conflicts between the parties” always happen in the construction industry.

The second problem always faced by respondents is cost overrun. Less than 50% construction logistics activities can be free from paying extra delivery fees for damages as well as issued in terms of amount, location and time plan.

According to Section 4.5 (ii) (a) to (c), the group of subcontractors experienced more frequent cost overrun if compared to the other group of contractor, supplier and logistics. This may because there are huge number of subcontractors involved in a project and about 75% of project final value is produced by them. It is aggravated with the improper management of construction logistics by the subcontractor (Segerstedt and Olofsson, 2010; Robbins, 2015; Tsaxiri, 2018).

The health and safety problem of workers is the third ranked problem which frequently faced by respondents. The respondents who work as deputy director or director experienced frequent worker safety and health problems than the respondents who work as assistant and executive (Section 4.5 (viii) (c) & (d)). Furthermore, the respondents who have more than 10 years working experience faced more problems related to health and safety of workers in his/her current and previous project compared to the respondents who have only working experience of less than 2 years, 3 to 5 years and 6 to 10 years (Section 4.5 (x) (a) to (d)). The result shows that the respondents who work as deputy or director or have more than 10 years working experience are more familiar with construction logistics activities as they have more experience and involve in various types of projects.

The group who always face problems with current construction logistics practices will realise the shortcomings and insufficiency of current practices. Consequently, by driven largely of widespread availability of trending digital technologies, they will tend to aware the revolution of Logistics 4.0 as well as adoption and development of AI.

4.12.2 Organisation's Awareness towards the Benefits of Logistics 4.0

Local construction organisations most concern Logistics 4.0 improves productivity in construction logistics. AI adoption and automation ensure the overall connection among various project parties. Cooperation between different project team is more aligned within transportation and operations processes. AI adoptions ensure construction logistics activities are free from errors by responding precisely (Schmidtke, et al., 2018). Hence, reduction of lead time in logistics provides higher productivity is a major concern of the industry.

The respondents also perceived that transparency and flexibility in construction logistics are improved with aids of technology such as AI. The flexibility of transportation setup and intralogistics can be improved when AI applications able to make fast and precise decisions in solving problems. Furthermore, fraud among logistics service providers can be detected by using the combination of RPA and AI (Klumpp, 2018). Respondents who perceived Logistics 4.0 has "extremely" incurred benefits to construction logistics tend to more concern about the development and adoption of AI in construction logistics.

4.12.3 Organisation's Awareness towards AI Adoption in Construction Logistics

a) Awareness on relevance of AI in construction logistics

The top three construction logistics activities with highest perception on relevance of AI are "process of contracts and invoices", "further planning after prediction of delay" and "planning and management of loading and unloading zones". Local construction organisations perceived that AI is the most relevant in processing contracts and invoices when every project has its own unique need, and all contracts and payables have to be controlled all the time. Thus, automation of contract and invoice process is important to save time and increase accuracy (Gesing, et al, 2018; Stampli, 2021). Suppliers are more perceived the relevance of AI in the top two construction logistics activities if compare to contractors (Section 4.6 (i) (a) & (d)). This may imply that suppliers who contracted to provide materials or goods more aware the transformation of AI adoption in their supply logistics for manufacturing and supply management. Moreover, deputy directors and directors as well as the respondents who worked more than 10 years perceived the top three construction logistics activities' higher relevance to AI if compared to assistant, executive and the respondents who worked less than 2 years and 3 years to 5 years (Section 4.6 (v)(a)(d)(f) & (viii)(a)(c)(e)(f)(g)). This implies that the superiors with more working experiences able to feel the AI disruptions and its competitive advantages to construction logistics. They have heightened awareness towards the development of AI in construction logistics when compare to subordinates who have fewer working experiences.

The third to last ranked construction logistics activities with only 66 respondents perceived “very” relevant to AI adoption is delivery and traffic management. This is opposed with findings of the research by McKinsey, et al. (2017) which indicates transportation is one of the sector with highest potential for automation. This may because most of the respondents misunderstood the word ‘relevance’ and they tend to interpret its meaning as how possible the reality of “delivery automation and traffic management automation” will come true in this few years. As these technologies are still under testing and validation all around the world and have not been adopted widespread, the respondents give the relevance of AI in “delivery and traffic management” a low rating.

In overall, the group perceived AI is “extremely” relevant to construction logistics activities in Table 4.6 have higher awareness towards AI adoption in construction logistics when compared with the group perceiving AI is “not at all”, “slight”, “moderately” and “very” relevant to construction logistics. This shows that this group which able to visualise relevance of AI is “extremely” relevant to construction logistics tends to perceive the potentials of AI development and more aggressive in exploring the uses of AI in construction logistics.

b) Awareness on functions of AI in construction logistics

The respondents most agreed on the “*AGV is useful for repetitive transportation works in warehouse*”. AGV can offer accurate navigation and safer transportation in warehouse by mapping their travel path without human intervention (Modern Material Handling, 2020). Respondents tend to have highest awareness towards usefulness of AGV if compared to other nine adoptions of AI in construction logistics. Respondents worked in logistics firm are more agreed the functions of AGV compared to other respondents who worked in contractor, sub-contractor, specialist and supplier firm (Section 4.7 (ii to v) (a)). They tend to have higher awareness and more likely understand the value of AGV in warehousing.

Next, the second ranked statements with 98 respondents strongly agreed the statements related the functions of AI-based drones. The traditional method in gathering information for site layout planning by walking around site can be replaced by AI-based drones. The innovation of AI-based drone eases this drudge preparation works by producing different types of detailed construction site map and site progress report automatically (Dukowitz, 2019).

The functions of AI-back offices ranked the third among other AI adoptions in construction logistics when 101 respondents slightly agreed on *"AI-back office is useful for detecting fraud by logistics service providers, classifying contractual clauses, managing and keeping all delivery information precisely"*. The combination of RPA and AI can well-cooperated in detecting fraud, automating processing of invoices as well as processing in classifying sections, clauses and signature portions in contracts. AI-back office ensures the correctness, completeness and consistency of billions of data (Gesing, et al., 2018).

These findings also reveal that the group with only 2 years or 3 to 5 years working experiences has the highest agreement on functions of AI adoption in construction logistics compared to those with 6 to 10 years or more than 10 years working experiences. This may imply that those with less working experience has a higher exposure towards the knowledge of AI development. These younger groups are grown alongside with these new introduced technologies which gradually related to their academic lessons. This is concurrent with the research of Meyer (2008) which indicated younger workers who less than 30 years old has higher acceptance towards new technology.

To conclude, the group who "strongly agree" the statements related to functions of AI adoptions in Table 4.7 has heightened awareness towards usefulness of AI adoptions in construction logistics compared to those who "slightly agree", "moderately', "slightly disagree" and "strongly agree". Comparatively, the group who "strongly agree" the functions of AI adoptions tend to accept the applications and more likely to resort to the particular AI adoption in construction logistics. They tend to more concern and appreciate the chances in learning and adopting AI. Moreover, they tend to foresee the potential barriers and issues which undermining the adopting of AI.

4.12.4 Existing Practices of AI in Construction Logistics

a) Organisations' plan for construction logistics activities with AI adoption

The construction logistics activity with highest level of organisations' planning in adopting AI is processing contracts and invoices. There are 105 of the respondents perceived that their organisations will adopt AI in processing their contracts and invoices in the next 3 years (Table 4.12). This finding is concurrent with collection of 45 RPA case studies by AI Mutiple which reveal that the most common area of RPA automation is invoice automation and most of the companies make their first purchase of AI product related to invoice capture because it is an easy integration solution (AI Mutiple, 2020; AI Mutiple, 2021a).

The on-site and off-site warehousing is the second ranked activities with perception of 95 of the respondents that their organisations are planning to adopt AI in the future of 3 years. Moreover, there are more than 50% of the respondents (80) perceived that their organisation's plan includes AI adoption in further planning after prediction of delay in 3 years. This implies that the overall adoption level of the existing AI adoptions in these top three construction logistics activities is higher than the other seven construction logistic activities in the near future.

These findings also reveal that the group with more than 10 years working experiences perceived their organisations have higher adoption of AI in "process of contracts and invoices" and "on-site and off-site warehousing" if compared to those with only 2 years, 3 to 5 years and 6 to 10 years working experiences (Section 4.8 (xii)(a)(c) & (xiii)(b)(d)). Respondents who have more working experience are more familiar with the operational plan in their organisations. However, respondents with less working experience have lower consensus towards organisations' plan on integrating AI into their organisation practices. These respondents who are fresh graduate and just enter the industry are still exploring the current practices in construction industry.

b) Organisations' existing AI adoption

The most planned AI to be adopted in construction logistics is UAV and UGV when 104 of the respondents perceived their organisations expect to use it in the next 3 years. The second ranked AI application is AGV when 103 respondents' organisation are expected to adopt it in 3 years. The findings reveal that the suppliers and logistics service providers more expect their organisations will adopt UAV and UGV, AGV and predictive analytics in the years ahead in their construction logistics if compared to contractor (Section 4.9 (iii) (a)(b)(d) & (v)(a to c)).

These findings also discover that most of existing practices of AI are under low adoption level in local construction organisations especially the smart construction lift, autonomous truck, unmanned tower crane and AI-developer kits which are the least perceived AI adoption in respondents' organisation plan in near future. For example, there are only 61 respondents perceived will adopt autonomous vehicles in their organisation in the future if able. This is concurrent to the findings of research by Kassim, et al. (2019) which indicated the autonomous vehicle (AV) readiness index in Malaysia and showed there was plenty of research work related AV technology was carried out. However, most of them were only in small scale of miniature robots and showed there was lack of efforts to adopt AV technology properly in Malaysia in the near future (Kassim, 2019).

4.12.5 Challenges in AI Adoption

The respondents most concern on the leadership commitment when adopting AI in construction activities. Innovation of AI in an organisation are comes along with high level of risk and uncertainty as well as enormous cost of implementation. Many companies are lack of capital in preparing resources and top management are reluctant to adopt AI to prevent cost overweight revenue (Omar, et al., 2017). There are tepid demands of AI innovation in construction industry when most of the construction organisations are refused to investment in AI adoption. Many of the leaders in an organisation are uncertain about what AI can done for them and what benefits will be bought along, where can get AI-powered applications, how to integrate it into their existing company software and how to assess its return on the investment (ROI) (Bughin, et al., 2017).

4.12.6 Readiness towards AI Adoption in Construction Logistics

In overall, Section 4.10 revealed that Malaysian construction industry aware Logistics 4.0 with aids of technology such as AI create competitive advantages to their organisations. Section 4.6 and 4.7 also shows that most of the respondents are aware of the AI disruption and usefulness to their organisations. However, Section 4.8 and 4.9 shows most of the organisations plan to have AI in the near future especially in 3 to 5 years instead of using now. This discovered that the overall adoption level of existing AI practices in local construction logistics activities is still low but expect increasing in 3 to 5 years.

These findings can be concluded that the Malaysian construction industry have stronger awareness towards adoption of AI in construction logistics if compared to actual existing adoption practices of AI. As a result, this implies that Malaysian construction industry is aware and acknowledge about innovation of AI and they are ready now for AI transformation and adoption in construction logistics. However, most organisations are not using AI adoptions now but expect having plan to adopt in the future, maybe in 3 to 5 years due to some challenges especially the first ranked challenges which is lack of leaders' commitment that should not be overlooked in adopting AI. AI innovation is challenging to be achieved in an organisation when it involves enormous investment and comes along with significant risk as well as uncertainty (Omar, et al., 2017).

It is concurrent with MHI Annual Industry Report which shows that only 12% of respondents are currently adopting AI technology, but more than 50% of respondents believe that AI is disrupting their industry and brings competitive advantages to their business. Thus, it is estimated the use of AI technology will keep increasing until 38% in 1 to 2 years and 60% in 3 to 5 years. The S-curve of innovation also indicates that the evolution of AI technology is slow now, but this evolution is increasing significantly within the next few years (Sunol, 2020).

In short, Malaysian construction organisation are aware and acknowledge AI trend in construction logistics. Local construction players are ready now for adopting AI in their logistics practices. Nevertheless, due to some barriers for AI adoptions in terms of technology, costs and commitments, most of the organisations are still at the beginning of planning for AI innovation in the near future and remain in its infancy of adopting AI now. AI adoption is not solely about technical adoption, it is about the acceptance of an organisation.

Momentum from executive leader is strongly needed to overwhelm organizational inertia in adopting AI.

4.13 Summary

This chapter introduces the background of targeted respondents and the results of data analysis for each section by using Shapiro-Wilk W test and Cronbach's Alpha reliability test. Next, the analysis results pertaining to problems faced in current construction practices, perception towards the relevance of AI, agreements towards the functions of AI, perceptions towards the organisation's plan for adoption of AI by using ranking by median and Mann-Witney test are shown in table respectively. Lastly, each of them and the readiness towards AI adoption in construction logistics are discussed and explained in detailed.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This is the last chapter in this research. The background is discussed in Section 5.2. The accomplishment of research objectives is presented in Section 5.3, follows by implications of this research in Section 5.4. The limitations and recommendations are reviewed in Section 5.5 and 5.6 respectively.

5.2 Summary of Background Study

In 21st century, it can be observed that the investments and demands related to artificial intelligence (AI) are accelerated at an unprecedented rate. The global AI market is booming during the outbreak of COVID-19 pandemic. This is because offices are forced to be closed and many companies have to use automation to continue their business for example payroll management (Koh, 2021).

In Malaysia, the productivity of employees is expected to be improved about 60% with AI applications. However, there are only 26% of the companies in Malaysia are currently adopting or planning now to integrate AI in their business (Paramasivam, 2019). It is a potential trend for AI. AI is expected to be adopted in construction industry in near future especially logistics sector by innovating applications unique to construction logistics or transferring existing applications from other industries. Nevertheless, construction industry is lagging behind from integration of AI in industry if compared to other industries. Based on study by McKinsey, it is approximately of 16% for AI adoption level in construction sector (Shackleton, 2019).

In the past decades, despite the low current adoption level, AI technologies are gradually introduced to construction communities and its disruptions are getting accepted. It is synergy between AI technologies with traditional practices as human-AI collaborations will provide competitive advantages to construction industry sector (Construction Industry Development Board, 2018).

Construction logistics is one of the main factor in bringing a project successfully. The shortcomings or problems related to supply logistics or site logistics may create a serious stranglehold to a project and cause unnecessary construction costs and time waste. Thus, the shortcomings pertaining to the current construction logistics practices have heightened the importance of AI automation and robotics technologies for traditional construction logistics practices. AI is the coming revolution to the world; it is vital for construction industry to embrace the AI technologies and optimize its opportunity in adopting especially in logistics sector.

5.3 Accomplishment of Research Objectives

This research outlines a brief account of AI, its structure and types, the explanation of construction logistics, problems in current construction logistics practices, the benefits of Logistics 4.0, AI adoptions in construction logistics and its challenges in Chapter 2. A theoretical framework of readiness of AI adoptions is developed and presented in Figure 2.10. Based on this theoretical framework, the framework of the questionnaire design is presented in Figure 3.4. There are 154 duly answered questionnaires were used in analysis and discussion. As reported in Chapter 4, the further findings were presented by descriptive statistics and some of them are tested by inferential statistics.

This research aims to examine the readiness of industrial players towards the adoption of AI in Malaysian construction logistics. There are three objectives which were outlined early in Chapter 1: (1) to uncover the problems faced in current construction logistics practices, (2) to identify the existing practices of AI in construction logistics and (3) to study the readiness of industrial players to adopt AI in the practices in construction logistics. In this research, the established objectives were fulfilled and summarized as followed:

Objective 1:

The respondents were asked to rate their frequency of facing problems happened to the construction logistics with their current and previous experiences. The top three most faced problems by construction players in Malaysia were revealed as: (1) lack of collaborations among parties; (2) cost overrun; (3) construction workers' health and safety are endangered by plants and vehicles on site. Air pollution caused by heavy vehicles was perceived as the least frequent happened in Malaysian construction logistics. The deeper analysis of these findings revealed that subcontractor experienced more problems related to cost overrun and time overrun in construction logistics if compared to contractor, suppliers and logistics services providers. It also revealed that respondents with more than 10 years working experience faced more problems related to health and safety of construction worker as well as lack of collaborations between parties if compared to those with less working experiences.

Obejective 2:

To accomplish the second objective, the respondents were requested to select whether their organizations are using the AI now in their construction logistics activities or are planning AI adoptions in 3 years, 5 years, in the future or not plan at all. The findings revealed that majority of the organizations are not using AI now in their practices but are planning to invest in AI applications in the years ahead. Most of the organization are planning to have AI applications in processing the contracts and invoices as well as further planning after prediction of delay in the next 3 years. The top listed AI applications with most potential of increasing adoption level in construction logistics in the next 3 years are (1) UAV and UGV, (2) AGV, (3) predictive analytics and (4) AI-based drones. The deeper analysis of these findings revealed that the superiors with more working experiences tend to more perceived their organization are planning for AI adoptions in near future if compared to subordinate with less working experiences. This shows superiors are more optimistic in expecting the adoption level of AI in construction logistics will increasing over the years ahead as a result of AI trends. In overall, the current adoption level for existing practices of AI in logistics of Malaysian construction industry is low when most of the organizations are expected to adopt AI in the near future, maybe 3 to 5 years.

Objective 3:

To accomplish the last objective, as illustrated in the theoretical framework, it is necessary to look into 3 elements: the organisations' awareness to AI adoption in construction logistics, the existing practices of AI in construction logistics and the challenges in adopting AI.

Majority of the respondents are aware and acknowledge the benefits of Logistics 4.0 and AI adoptions in construction logistics. The findings discovered that the most concerned benefit of Logistics 4.0 by Malaysian construction organisations is improvement of productivity. There are total of seven activities related to construction logistics are discussed in this research. It reveals that the local construction organisations have higher awareness on the processing of contracts and invoices by AI applications. Furthermore, among the ten AI adoptions identified, the construction players most aware to the functions of UAV and UGV.

The deeper analysis revealed that the superiors with more working experiences have relatively higher awareness towards the relevance of AI to construction logistics (Section 4.6) whereas the younger generation with less working experience are more aware to the functions of each listed AI applications (Section 4.7). This may because superiors tend to have better visualisation towards potential of AI applications in construction logistics but they aware each existing AI applications still have room of improvements for their functions listed in this research. In overall, no matter individuals’ working experiences or job position, the local organisations have relatively high awareness towards AI development in construction logistics.

However, the actual adoption level for existing practices of AI in current construction logistics is low. Most of the organisations are planning to have AI in the years ahead instead of adopting now. This may be due to lack of commitment of leaders in investment which is the major barrier of undermining the AI adoption. Although it is expected AI adoption will be increased in the next few years, AI transformation of an organisation is still challenging for investing sufficient resources in terms of advanced technologies, skills and high implementation cost.

In conclusion, Malaysian construction industry has stronger awareness and acknowledgement about AI trend in construction logistics if compared to actual adoption practices of AI. As a result, this implies that Malaysian construction industry is ready now for AI transformation and adoption in construction logistics but due to some challenges which cause most of the organisations are not adopting AI now but planning to use in the years ahead. Figure 5.1 summarises the key findings in this research.

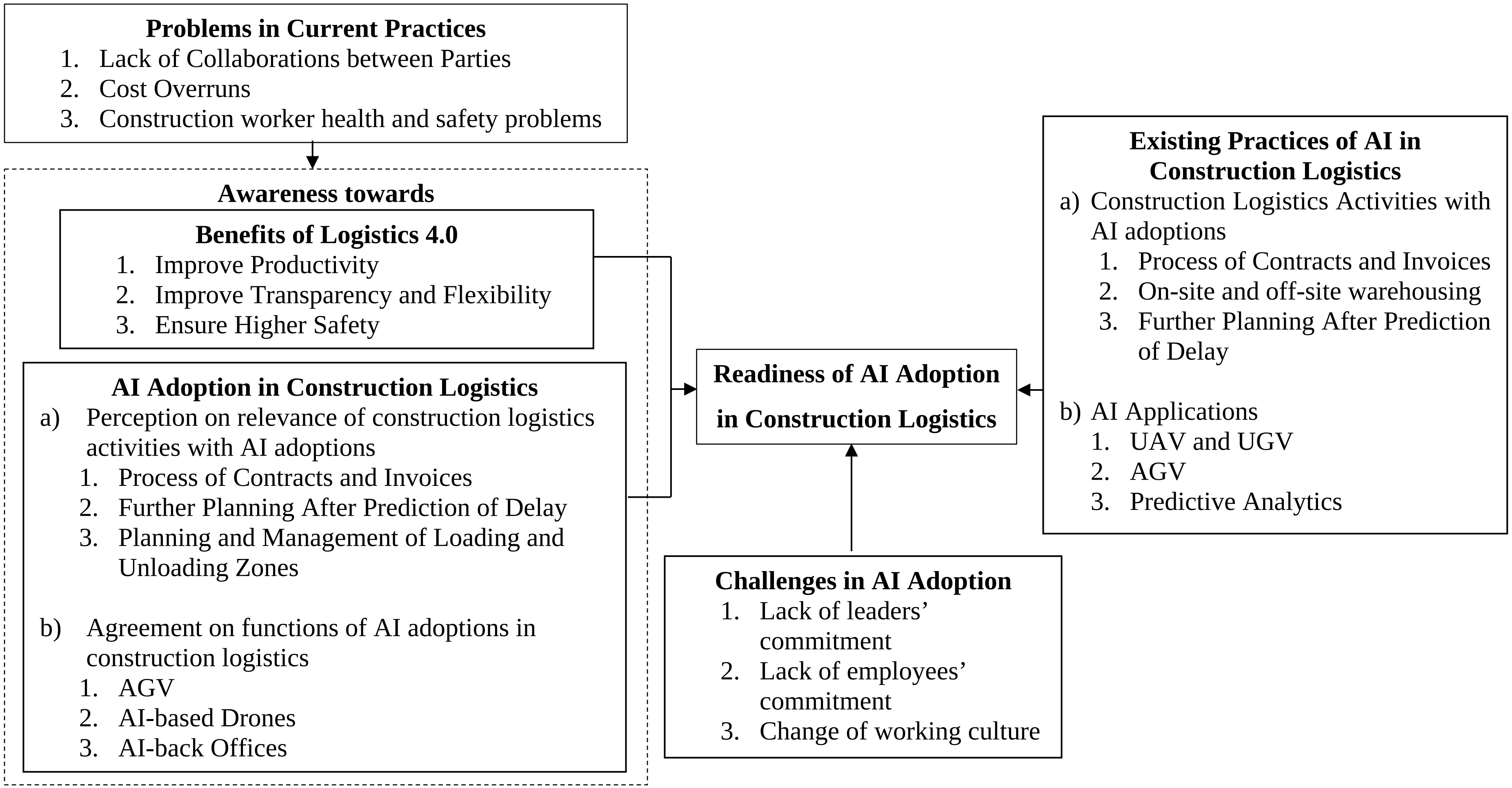


Figure 5.1: Summary of Key Findings

5.4 Research Implication

This research provides the fundamental and core knowledge of AI to construction organisations. Through this research, their awareness on AI development in logistics industry is enhanced. It is expected the construction community can be benefit by the further findings of this research in gradually equipping themselves towards the revolution of new advanced technology such as AI.

In overall, the findings in this research shows Malaysian construction industry is ready now in transformation and adopting AI in their logistics practices. Most of them are aware of the disruption of AI and its competitive advantages. However, it is lack of investment in AI technology in construction logistics. The achievement of transformation for AI requires the concern and willing of all parties in construction industry. Hopefully, these findings can alert all of the construction practitioners in Malaysia to prepare themselves in coping with AI trend in their business. On the other hand, it is expected that the local government will make proactive action in enhancing the revolutions of new advanced technology in near future.

The overview of the current readiness status in Malaysian construction logistics sector acts as a threshold for the other researchers who conduct research on similar or narrower topic for example the uses of particular AI in construction industry. On the other hand, this research is also providing awareness to the university to update their syllabus and arrange new short courses related to advanced technology such as AI. This may ensure young generations are more acknowledge and more exposed to these new knowledges and skills in future.

5.5 Research Limitations

There are some limitations in this research. Firstly, the sample size is determined by using Central Limit Theorem (CLT). Data is obtained with number of samples equal or more than 30 which considered as reasonable accurate with sufficient size of samples as stated in Section 3.9.3. However, the actual profile of population in the construction industry may not reflected with the sample size of respondents in this research.

Furthermore, the convenience sampling method used in this research may not be the best method in obtaining data. The selection of respondents is based on their convenience and availability. The structure of the population may not be reflected by the structure of respondents in this research. In addition, the innovation and development of artificial intelligence is too fast and hard to keeping up to date. Thus, the questionnaire designed in this research may not cover the latest AI development and approaches.

5.6 Research Recommendations

There are some recommendations for future similar research. The sample size can be determined and obtained based on Cochran's formula as larger sample size will provide more accurate information. Furthermore, qualitative research such as interviews may be conducted in examining the readiness of AI adoption in Malaysian construction logistics in future to overcome the weakness of the quantitative research. Some factors regarding to AI trend in Malaysian construction logistics may be undetected and not included in the questionnaire. More professional and rich contents can be obtained by conducting interviews. In addition, it is recommended to adopt stratified random sampling in the future research to ensure accurate representative of sample which are more appropriate and meaningful to the research. A narrower and more precise scope of research may be defined to ensure researcher can more focusing on specific topic such as specific AI application in construction logistics.

5.7 Summary

This last chapter reveals that the summary of background in this study, the accomplishments of research objectives. This chapter also discusses about the implications, limitations and recommendations in this research.

REFERENCES

Aamoth, D., 2014. Interview with Eugene Goostman, the Fake Kid Who Passed the turing Test. *Time,* [online] 9 June. Available at: < https://time.com/2847900/eugene-goostman-turing-test/> [Accessed 8 July 2020].

Abeysinghe, A.M.G.P., Waidyasekara, K.G.A.S. and Melagoda, D.G., 2018, May. Beyond Site Material Handling and Transportation in Large-Scale Construction Projects. *In 2018 Moratuwa Engineering Research Confrence (MERCon)* (pp. 66-71). IEEE.

Ahn, H., Lee, D., Lee, S., Kim, T., Cho, H. and Kang, K.I., 2018. Application of Machine Learning Technology for Construction Site. In ISARC. *Proceedings of the International Symposium on Automation and Robotics in Construction* (Vol. 35, pp. 1-8). IAARC Publications.

AI Mutiple, 2020. *45 RPA Case Studies; Explore RPA in your Industry & Function* [online] 20 September. Available at: < https://research.aimultiple.com/rpa-case-studies/> [Accessed 27 March 2021].

AI Mutiple, 2021a. *Invoice Capture: Guide to most firm's first AI purchase in 2021*. [online] 21 January. Available at: < https://research.aimultiple.com/invoice-capture/> [Accessed 27 March 2021].

AI Mutiple, 2021b. *In-depth Guide to Automating Invoice Processing in 2021*. [online] 1 January. Available at: < https://research.aimultiple.com/invoice-automation/> [Accessed 27 March 2021].

Alahmad, R. and Robert, L., 2020, May. Artificial Intelligence (AI) and IT identity: Antecedents Identifying with AI Applications. In Alahmad, R. and Robert, LP (2020). *Artificial Intelligence (AI) and IT identity: Antecedents Identifying with AI Applications, Proceedings of the 26th Americas Conference on Information Systems, Aug* (pp. 13-15).

Barreto, L., Amaral, A. and Pereira, T., 2017. Industry 4.0 implications in logistics: an overview. *Procedia Manufacturing, 13,* pp.1245-1252.

Bell, M. L., and HEI Health Review Committee, 2012. Assessment of the health impacts of particulate matter characteristics. *Research report Health Effects Institute,* (161), pp.5–38.

Blanco, J. L., Fuchs, S., Parsons, M., and Ribeirinho, M. J., 2018. *Artificialintelligence: Construction technology's next frontier*. [online]. Available at: <https://www.mckinsey.com/industries/capital-projects-and infrastructure/ourinsights/artificial-intelligence-construction-technologys-next-frontier> >[Accessed 17 August 2020].

Brown, A., 2013. The role of a construction logistics manager. *Logistics & Transport Focus,* 15(8), pp.1-4.

Browne, M., 2015. Effective management of a construction project supply chain. *Supply Chain Management and Logistics in Construction: Delivering Tomorrow's Built Environment*, pp.9-23.

Bomb, A. and Haraldsdottir, H., 2017. *Four perspectives on urban construction logistics: Why it matters and how to make it*. [online] University of Gothenburg. Available at: < https://gupea.ub.gu.se/bitstream/2077/52787/1/gupea_2077_52787_1.pdf> [Accessed 17 July 2020].

Buglin. J., Hazan. E., Ramaswamy. S., Chui. M., Allas. T., Dahlstrom. P., Henke. N. and Trench. M., 2017. *Artificial Intelligence The Next Digital Frontier?* [online] Available at: < https://www.mckinsey.com/~/media/mckinsey/industries/advanced%20electronics/our%20insights/how%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/mgi-artificial-intelligence-discussion-paper.ashx> [Accessed 29 March 2021].

Businesswire, 2020. *Global Forecast on Artificial Intelligence (AI) in the Freight Transportation Industry (2020-2025).* [online] Available at: < https://www.businesswire.com/news/home/20200207005450/en/Global-Forecast-Artificial-Intelligence-AI-Freight-Transportation> [Accessed 1 August 2020].

C, S., 2019, October. Logistics 4.0: Definition and Historical Background. *In 2019 Novel Intelligent and Leading Emerging Sciences Conference (NILES)* (Vol. 1, pp. 46-49). IEEE.

Chihara, L. M. & Hesterberg, T. C., 2011. *Mathematical Statistics with Resampling and R.* 2nd ed. Hoboken: John Wiley & Sons, Inc. Copeland, B., 2019. *Artificial intelligence.* [Online] Available at: https://www.britannica.com/technology/artificialintelligence/Reasoning [Accessed 2 February 2021].

Cochran, W.G., 1977. *Sampling Techniques.* 3rd ed. New York: John Wiley & Sons.

Construction Industry Development Board, 2018. *Statistics, Indices in Construction and Automation (SICA) Forum 2019.* [online] Available at: < https://www.cidb.gov.my/sites/default/files/2020-04/SICA-Forum-2018---Ministers-Opening-Keynote.pdf/> [Accessed 6 August 2020].

Creswell, J.W. and Creswell, J.D., 2018. *Research Design Qualitative, Quantitative and Mixed Methods Approaches.* 5th ed. Los Angelas: Sage.

Cubric, M., 2020. Drivers, barriers and social considerations for AI adoption in business and management: A tertiary study. *Technology in Society, p.101257.*

Cui, R., Li, M. and Zhang, S., 2020. AI and Procurement. *Available at SSRN.*

Das, S.K. and Pasan, M.K., 2016. Design and methodology of automated guided vehicle-a review. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, pp.29-35.

Dietvorst, B.J., Simmons, J.P. and Massey, C., 2015. Algorithm aversion: People erroneously avoid algorithms after seeing them err. *Journal of Experimental Psychology: General, 14*4(1), p.114.

Doyle, A., 2020. *What is Deductive Reasoning?*. [online]. Available at: < https://www.thebalancecareers.com/deductive-reasoning-definition-with-examples-2063749> [Accessed 9 February 2021].

Dukowitz, Z., 2019. *Companies Save Money, Improve Safety Conditions and Keep Customers Happy.* [online]. Available at: < https://uavcoach.com/drones-in-construction/> [Accessed 24 July 2020].

Ekeskär, A., 2016. *Exploring Third-Party Logistics and Partnering in Construction:* A Supply Chain Management Perspective (Vol. 1753). Linköping University Electronic Press.

Ekeskär, A. and Rudberg, M., 2016. Third-party logistics in construction: the case of a large hospital project. *Construction management and economics, 34*(3), pp.174-191.

Ergen, M., 2019. What is Artificial Intelligence? Technical Considerations and Future Perception. *Anatolian journal of cardiology*, 22(Suppl 2), pp.5-7.

Facchini, F., Oleśków-Szłapka, J., Ranieri, L. and Urbinati, A., 2020. A maturity model for logistics 4.0: An empirical analysis and a roadmap for future research. *Sustainability, 12*(1), p.86.

Faggella, D., 2020. *What Is Artificial Intelligence? An Informed Definition | Emerj*. [online] Emerj. Available at: <https://emerj.com/ai-glossary-terms/what-is-artificial-intelligence-an-informed-definition/> [Accessed 6 July 2020].

Gaw, D., 2019. *How jobsite cameras are evolving in use and capability*. [online]. Available at: <https://www.enr.com/articles/47065-jobsite-cameras-past-present-future> [Accessed 17 August 2020].

Gesing, B., Peterson, S.J. and Michelsen, D., 2018. Artificial intelligence in logistics. A collaborative report by DHL and IBM on implications and use cases for the logistics industry. *DHL Customer Solutions & Innovation*, p.45.

Glistau, E. and Coello Machado, N.I., 2018. Industry 4.0, Logistics 4.0 and materials-chances and solutions. *In Materials Science Forum* (Vol. 919, pp. 307-314). Trans Tech Publications Ltd.

Gheisari, M. and Esmaeili, B., 2016. Unmanned aerial systems (UAS) for construction safety applications. *In Construction Research Congress 2016* (pp. 2642-2650).

Guérin, F., Guinand, F., Brethé, J.F. and Pelvillain, H., 2016, December. Towards an autonomous warehouse inventory scheme. In *2016 IEEE Symposium Series on Computational Intelligence (SSCI)* (pp. 1-8). IEEE.

Guerlain, C., Renault, S. and Ferreror, F., 2019. Understanding Construction Logistics in Urban Areas and Lowering Its Environmental Impact: A Focus on Construction Consolidation Centres. *Sustanability 2019, 11,* pp1-11.

Hall, P., Dean, J., Kabul, I.K. and Silva, J., 2014. *An Overview of Machine Learning with SAS Enterprise Miner*. [online] Available at: < https://support.sas.com/resources/papers/proceedings14/SAS313-2014.pdf> [Accessed 7 July 2020].

Hao, K., 2019. Training a single AI model can emit as much carbon as five cars in their lifetimes. *MIT Technology Review.*

Health and Safety Executive, 2020. *Traffic management on site*. [online] Available at: < https://www.hse.gov.uk/construction/safetytopics/vehiclestrafficmanagement.htm#:~:text=The%20law%20says%20that%20you,routes%20can%20move%20around%20safely.&text=The%20key%20message%20is%3A%20construction,operations%20throughout%20the%20construction%20process.> [Accessed 18 July 2020].

Heller, C.H., 2019. Near-Term Applications of Artificial Intelligence. *Naval War College Review*, 72(4), pp.73-100.

Hsu, P.Y., Aurisicchio, M. and Angeloudis, P., 2017, July. Supply chain design for modular construction projects. IGLC.

Hsu, P.Y., Aurisicchio, M. and Angeloudis, P., 2019. Optimal logistics planning for modular construction using multi-stage stochastic programming. *Transportation Research Procedia*, *46*, pp.245-252.

Iansiti, M. and Lakhani, K.R., 2020. *Competing in the Age of AI: Strategy and Leadership When Algorithms and Networks Run the World*. Harvard Business Press.

Igliński, H. and Babiak, M., 2017. Analysis of the potential of autonomous vehicles in reducing the emissions of greenhouse gases in road transport. *Procedia engineering*, *192*, pp.353-358.

Kaplan, A. and Haenlein, M., 2020. Rulers of the world, unite! The challenges and opportunities of artificial intelligence. *Business Horizons*, *63*(1), pp.37-50.

Kassim, K.A., Jawi. Z., Nasruddin. M. A., 2019. Is Malaysia Ready to Adopt Autonomous Vehicles? [online] Available at: < https://www.researchgate.net/publication/334671296 /> [Accessed 29 March 2021].

Keary, T., 2019. *AI and OCR: How optical character recognition is being revitalized.* [online] Available at: <https://www.information-age.com/optical-character-recognition-tools-ocr-ai-123479324/> [Accessed 27 March 2021].

Kiran, B.R., Sobh, I., Talpaert, V., Mannion, P., Sallab, A.A.A., Yogamani, S. and Pérez, P., 2020. Deep reinforcement learning for autonomous driving: A survey. *arXiv preprint arXiv:2002.00444.*

Koh, M., 2021. *The AI Industry is Booming- Make Sure Your Technology is Ahead of The Competition*. [online] Enterprisetehsuccess. Available at: < https://www.enterprisetechsuccess.com/article/The-AI-industry-is-booming---Make-sure-your-technology-is-ahead-of-the competition/UCtodUtvSm05ckQvWGVYaHJsZ3lmdz09/> [Accessed 8 April 2021].

Klumpp, M., 2018. Innovation Potentials and Pathways Merging AI, CPS, and IoT. *Applied System Innovation, 1*(1), p.5.

Kopelias, P., Demiridi, E., Vogiatzis, K., Skabardonis, A. and Zafiropoulou, V., 2020. Connected & autonomous vehicles–Environmental impacts–A review. *Science of the total environment, 712*, p.135237.

Laerd, 2012. *Convenience sampling?* [online] Available at: < https://dissertation.laerd.com/convenience-sampling.php> [Accessed 6 February 2021].

Laerd, 2018a. *Descriptive and Inferential Statistics.* [online] Available at: < https://statistics.laerd.com/statistical-guides/descriptive-inferential-statistics.php > [Accessed 8 February 2021].

Laerd, 2018b. *Cronbach's Alpha using SPSS Statistics.* [online] Available at: < https://statistics.laerd.com/spss-tutorials/cronbachs-alpha-using-spss-statistics.php > [Accessed 8 February 2021].

Laerd, 2018c. *Chi-Square Goodness-of-fit Test in SSS Statistics.* [online] Available at: <https://statistics.laerd.com/spss-tutorials/chi-square-goodness-of-fit-test-in-spss-statistics.php> [Accessed 8 February 2021].

Laerd, 2018d. *Friedman Test in SPSS Statistics.* [online] Available at: <https://statistics.laerd.com/spss-tutorials/friedman-test-using-spss-statistics.php> [Accessed 12 March 2021].

Laerd, 2018e. *Testing for Normality using SPSS Statistics.* [online] Available at: <https://statistics.laerd.com/spss-tutorials/testing-for-normality-using-spss-statistics.php> [Accessed 17 February 2021].

Lanko, A., Vatin, N. and Kaklauskas, A., 2018. Application of RFID combined with blockchain technology in logistics of construction materials. In *Matec Web of conferences* (Vol. 170, p. 03032). EDP Sciences.

Lauterbach, B.A. and Bonim, A., 2016. Artificial intelligence: A strategic business and governance imperative. *NACD Directorship, September/October*, pp.54-57.

Lewandowska, W.K. and Olejnik, K.M., 2019. Logistics 4.0 Maturity in Service Industry: Empirical Research Results. *Procedia Manufacturing, 38*, pp.1058-1065.

Li, H., Chan, G., Wong, J.K.W. and Skitmore, M., 2016. Real-time locating systems applications in construction. *Automation in Construction, 63*, pp.37-47.

Li, Z., Shen, G.Q. and Xue, X., 2014. Critical review of the research on the management of prefabricated construction. *Habitat international*, *43*, pp.240-249.

Lindén, S. and Josephson, P.E., 2013. In-housing or out-sourcing on-site materials handling in housing?. *Journal of engineering, design and technology*.

Livotov, P., Sekaran, A.P.C., Law, R., Reay, D., Sarsenova, A. and Sayyareh, S., 2019. Eco-innovation in process engineering: contradictions, inventive principles and methods. *Thermal Science and Engineering Progress, 9*, pp.52-65.

Lorica, B. and Loukides, M., 2016. *What is Artificial Intelligence?* [online] Available at: < https://www.oreilly.com/radar/what-is-artificial-intelligence/> [Accessed 6 July 2020].

Lundesjö, G. ed., 2015. *Supply chain management and logistics in construction: delivering tomorrow's built environment*. Kogan Page Publishers.

Mahmud, S.H., Assan, L. and Islam, R., 2018. Potentials of internet of things (IoT) in malaysian construction industry. *Annals of Emerging Technologies in Computing (AETiC), Print ISSN*, pp.2516-0281.

Marsal-Llacuna, M.L., Colomer-Llinàs, J. and Meléndez-Frigola, J., 2015. Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative. *Technological Forecasting and Social Change, 90*, pp.611-622.

Mangiafico, S. S., 2016. *Kruskal-Wallis Test*. Available at: < https://rcompanion.org/handbook/F_08.html> [Accessed 9 February 2021].

Maskuriy, R., Selamat, A., Ali, K.N., Maresova, P. and Krejcar, O., 2019. Industry 4.0 for the construction industry—how ready is the industry?. *Applied Sciences, 9*(14), p.2819.

Matouzko, Y., 2015. *Efficient Construction Logistics, A case study of an Office Block Project*. [online] DiVA. Available at: <http://www.diva-portal.org/smash/get/diva2:839478/fulltext01.pdf> [Accessed 18 July 2020].

Matyushenko, I., Berenda, S., Shtal, T. and Grigorova-Berenda, L., 2019. Logistics and transport in industry 4.0: perspective for Ukraine. In *SHS Web of Conferences* (Vol. 67, p. 03008). EDP Sciences.

McKinsey Global Institute, 2017. *Reinventing construction: A route to higher productivity*. [online] Available at: <https://www.mckinsey.com/~/media/McKinsey/Industries/Capital%20Projects%20and%20Infrastructure/Our%20Insights/Reinventing%20construction%20through%20a%20productivity%20revolution/MGI-Reinventing-Construction-Executive-summary.pdf> [Accessed 17 July 2020].

McKinsey, 2017. *Smartening up with Artificial Intelligence (AI) - What's in it for Germany and its Industrial Sector?* [online] Available at: < https://www.mckinsey.com/~/media/mckinsey/industries/semiconductors/our%20insights/smartening%20up%20with%20artificial%20intelligence/smartening-up-with-artificial-intelligence.ashx> [Accessed 27 March 2021].

McKinsey, Manyika. J., Chui. M., Miremadi. M., Bughin. J., George. K., Willmott. P., Dewhurst. M., 2017. *A Future that Works: Automation, Employment and Productivitiy*. [online] Available at: < https://www.mckinsey.com/~/media/mckinsey/featured%20insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works-Executive-summary.ashx> [Accessed 27 March 2021].

Melnikovas, A., 2018. Towards an explicit research methodology futures studies. *Journal of Future Studies, 23(2).0003*, p.33-39.

Mesjasz-Lech, A., 2016. Urban air pollution challenge for green logistics. *Transportation Research Procedia, 16*, pp.355-365.

Meyer, J., 2008. *The Adoption of New Technologies and the Age Structure of the Workforce.* [online] Available at: <ftp://ftp.zew.de/pub/zew-docs/dp/dp08045.pdf> [Accessed 1 April 2021].

Ministry of International Trade & Industry Malaysia, 2019. *MIMOS and Microsoft's Artificial Intelligence Centre to Accelerate Malaysia's Industry 4.0*. [online]. Available at: <https://www.miti.gov.my/miti/resources/Media%20Release/Malaysias_AI_Centre_(MIMOS_Microsoft_MITI).pdf> [Accessed 1 August 2020].

Modern Material Handling, 2020. AGVs & mobile robots. *Computers & Applied Sciences Complete*, *75*(5), pp50-54.

Moone, B., 2015. Construction supply chain management strategy. *Supply Chain Management and Logistics in Construction–Delivering Tomorrow's Built Environment*. London: Kogan Page Limited, pp.77-87.

Motalebi, S., 2020. *Analysis of Cosmic Microwave Background with Deep Learning* (Doctoral dissertation, Institute for Advanced Studies in Basic Sciences).

National Science & Technology Council and United States Department of Transportation, 2020. *Ensuring American Leadershp in Automated Vehicle Technolgies.* [online]. Available at: <https://www.transportation.gov/sites/dot.gov/files/docs/policyinitiatives/automated-vehicles/360956/ensuringamericanleadershipav4.pdf>[Accessed 19 July 2020].

National Highway Traffic Safety Administration, 2013. *Preliminary Statement of Policy Concerning Automated Vehicles.* [online] Available at: < https://www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf> [Accessed 22 July 2020].

Neuman, W.L., 2014. *Social Research Methods: Qualitative and Quantitative Approach*. 7th ed. London: Pearson.

Ngo, J., Hwang, B.G. and Zhang, C., 2020. Factor-based big data and predictive analytics capability assessment tool for the construction industry. *Automation in Construction, 110*, p.103042.

Nishant, R., Kennedy, M. and Corbett, J., 2020. Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda. *International Journal of Information Management, 53*, p.102104.

Noponen, N., 2019. Impact of Artificial Intelligence on Management. *Electronic Journal of Business Ethics and Organization Studies*, 24(2).

Nurain, M.S., 2015. *The Effect of Oversized Lane Width and Lane Shoulder on Heavy Vehicles Parking on Residential Streets*. [online]. Available at: < http://eprints.utm.my/id/eprint/53550/1/NurainMohdSithMFAB2015.pdf>[Accessed 19 July 2020].

NVIDIA, 2020. *Jetson AGX Xavier*. [online], Available at: < https://www.nvidia.com/en-us/autonomous-machines/embedded systems/jetson-agx-xavier/> [Accessed 17 August 2020].

Omar, S.A., Hasbolah, F. and Zainudin, U.M., 2017. The Diffusion of Artificial Intelligence in Governance of Public Listed Companies in Malaysia. *Int. J. Business, Econ. Law*, *14*(2), pp.1-9.

Oleśków-Szłapka, J. and Stachowiak, A., 2018, September. The framework of logistics 4.0 maturity model. In *International Conference on Intelligent Systems in Production Engineering and Maintenance* (pp. 771-781). Springer, Cham

Paramasivam, S., 2019. *Artificial Intelligence to nearly double the rate of innocation in Malaysia by 2021: Microsoft Study*. [online]. Available at: < https://news.microsoft.com/en-my/2019/04/02/artificial-intelligence-to-nearly double-the-rate-of-innovation-in-malaysia-by-2021-microsoft-study/> [Accessed 31 July 2020].

Park, L., 2020. Coroner: Franklin man, 48, killer in Hamilton construction accident. *Journal-News*, [online] 17 July. Available at: < https://www.journal-news.com/news/coroner-franklin-man-48-killed-in-hamilton-construction-accident/VTPJAFYH25DIHLHDK7OHVRRPQY/> [Accessed 18 July 2020].

Peng, J., Parnell, J. and Kessissoglou, N., 2019. A six-category heavy vehicle noise emission model in free-flowing condition. *Applied Acoustics*, *143*, pp.211-221.

Perugu, H., Wei, H. and Yao, Z., 2016. Integrated data-driven modeling to estimate PM2. 5 pollution from heavy-duty truck transportation activity over metropolitan area. *Transportation Research Part D: Transport and Environment*, *46*, pp.114-127.

Prahl, A. and Van Swol, L., 2017. Understanding algorithm aversion: When is advice from automation discounted*?*. *Journal of Forecasting*, *36*(6), pp.691-702

Price Waterhouse and Coopers & Lybrand (PWC), 2017. *AI to drive GDP gains of $15.7 trillion with productivity, personalisation improvements.* [online]. Available at: <https://www.pwc.com/gx/en/news-room/press-releases/2017/ai-to-drive-gdp-gains-of-15_7-trillion-with-productivity personalisationimprovements.html#:~:text=AI%20will%20contribute%20%24 15.7%20trillion,over%20the%20period%202016%2D2030.accident/VTPJAF YH25DIHLHDK7OHVRRPQY/> [Accessed 1 August 2020].

Qu, T., Lei, S.P., Wang, Z.Z., Nie, D.X., Chen, X. and Huang, G.Q., 2016. IoT-based real-time production logistics synchronization system under smart cloud manufacturing. *The International Journal of Advanced Manufacturing Technology*, *84*(1-4), pp.147-164.

Rai, A., Constantinides, P. and Sarker, S., 2019. Editor'S comments: next-generation digital platforms: toward human–AI hybrids. *Mis Quarterly*, 43(1), pp.iii-x.

Robbins, S., 2015. Effective management of a construction project supply chain. *Supply Chain Management and Logistics in Construction: Delivering Tomorrow's Built Environment*, pp.62-75.

Salvén, E., 2013. *Distribution centres in construction logistics* (Master's thesis).

Saunders, M., Lewis, P. and Thornhill, A., 2019. *Research Methods for Business Students*. 8th ed. New York: Pearson.

Savić, D., 2019. Are we ready for the future? Impact of Artificial Intelligence on Grey Literature Management. In *Conference on Grey Literature and Repositories* (p. 6).

Schmidtke, N., Behrendt, F., Thater, L. and Meixner, S., 2018, April. Technical potentials and challenges within internal logistics 4.0. *In 2018 4th International Conference on Logistics Operations Management (GOL*) (pp. 1-10). IEEE.

Segerstedt, A. and Olofsson, T., 2010. Supply chains in the construction industry. *Supply chain management: an international journal, 15*(5), pp. 347-353
Sekaran, U. and Bougie, R., 2016. *Research methods for business: a skill-building approach.* 7th ed. Chichester: Jon Wiley & Sons Ltd.

Shackleton, O., 2019. *Construction Industry lacks in artificial intelligence integration*. [online]. Available at: https://www.cdrecycler.com/article/construction-industry-lacks-artificial-intelligence/#:~:text=Construction%20is%20falling%20behind%20in,integrating%20AI%20into%20their%20businesses.&text=Construction's%20AI%20adoption%20rate%20was%20approximately%2016%20percent.> [Accessed 8 April 2021].

Sisko, 2019. *Construction Logistics*. [online]. Available at: < https://www.sisko-worldwide.com/our-industry/construction/ > [Accessed 23 July 2020].

Sivalingam, P., 2020. How artificial intelligence willchange the construction sector. *The Star*, [online] 9 March. Available at: <http https://www.thestar.com.my/business/business-news/2020/03/09/how-artificial-intelligence-will-change-the-construction-sector> [Accessed 5 July 2020].

SSI Schaefer Whitepaper, 2018. *Artificial Intelligence in Logistics*. [online] Available at: <https://www.ssi-schaefer.com/resource/blob/566408/06d87a3eff1abfbdd7af3875404b724a/white-paper-artificial-intelligence-in-logistics--dam-download-en-16558data.pdf> [Accessed 7 July 2020].

Stampli, 2021. *AP Automation for Construction*. [online]. Available at: < https://www.stampli.com/construction/> [Accessed 27 March 2021].

Sternad, M., Lerher, T. and Gajšek, B., 2018. Maturity levels for logistics 4.0 based on NRW's Industry 4.0 maturity model. *Business Logistics in Modern Management.*

Strandhagen, J.O., Vallandingham, L.R., Fragapane, G., Strandhagen, J.W., Stangeland, A.B.H. and Sharma, N., 2017. Logistics 4.0 and emerging sustainable business models. *Advances in Manufacturing, 5*(4), pp.359-369.

Sundquist, V., Gadde, L.E. and Hulthén, K., 2018. Reorganizing construction logistics for improved performance. *Construction management and economics, 36*(1), pp.49-65.

Sunol. H., 2020. *Warehouse Technology: Artificial Intelligence (AI).* [online] 8 August. Available at: <https://articles.cyzerg.com/warehouse-technology-artificial-intelligence-ai> [Accessed 29 March 2021].

Telese, G. and Hedlund, R., 2019. *Outsourcing Construction Logistics-Organising construction deliveries using Third-Party Logistics* (Master's thesis).

The Straits Times, 2021. Two women killed as part of bridge under construction in KL collapses on can they are in. *The Straits Times.* [online] 2 March. Available at: <https://www.straitstimes.com/asia/se-asia/two-malaysian-women-killed-when-part-of-a-bridge-construction-collapsed-in-kl> [Accessed 27 March 2021].

Thunberg, M., Rudberg, M. and Gustavsson, T.K., 2017. Categorising on-site problems. *Construction innovation.*

Transport for London, 2017. *Construction Logistics Plan Guidance*. [online] Available at: <http://content.tfl.gov.uk/construction-logistics-plan-guidance.pdf> [Accessed 17 July 2020].

Transport Topics, 2018. *Smart Ports: When AI Takes Over Shipping*. [online] Available at: <https://www.ttnews.com/articles/smart-ports-when-ai-takes-over-shipping> [Accessed 23 July 2020].

Tsaxiri, P., 2018. *Problems and Solutions in Urban Construction Logistics.*[online] DiVA. Available at: <http://content.tfl.gov.uk/construction-logistics-plan-guidance.pdf> [Accessed 18 July 2020].

Tucker, C., Agrawal, A., Gans, J. and Goldfarb, A., 2018. Privacy, algorithms, and artificial intelligence. *The Economics of Artificial Intelligence: An Agenda*, pp.423-437.

Turner, A.G., 2003. *Sampling frames and master samples*. United Nations Secretariat Statistics Division.

UK's Department for International Trade, 2017. *How 9 industrial are being transformed by UK innovation around the world.* [online] Available at: < https://www.businessinsider.com/sc/artificial-intelligencecompanies?IR=T> [Accessed 1 August 2020].

United States Energy Information Administration, 2020. *June 2020: Monthly Energy Review*. [online]. Available at: <http://content.tfl.gov.uk/construction-logistics-plan-guidance.pdf> [Accessed 22 July 2020].

University of Southern California, 2015. *Research Output Reporting*. [online]. Available at: < https://libguides.usc.edu.au/HERDC-ERA> [Accessed 12 August 2020].

Volve CE, 2018. *Volve Ce Tests Safety Concepts with Colas*. [online]. Available at:<https://www.volvoce.com/global/en/news-and-events/press-releases/2018/volvo-ce-tests-safety-concepts-with-colas/> [Accessed 25 Jan 2021].

VolvoCE, 2019. *Infographic: The Rise of Artificial Intelligence in Construction.* Available at:< https://www.volvoce.com/global/en/news-and-events/news-and-stories/2019/infographic-the-rise-of-artificial-intelligence-in-construction/> [Accessed 25 Jan 2021].

Volvo Trucks, 2019. *Vera's first assignment: Volvo Trucks presents an autonomous transport between a logistics centre and port*. [online]. Available at:<https://www.volvogroup.com/content/dam/volvo/volvogroup/markets/global/en-en/news/2019/jun/Vera-s-first-assignment-press release-2019-06-13-07-00-33.pdf> [Accessed 23 July 2020].

Wang, K., 2016, November. Logistics 4.0 Solution-New Challenges and Opportunities. *In 6th International Workshop of Advanced Manufacturing and Automation.* Atlantis Press.

Wang, P., 2008, March. What Do You Mean by``AI"?. In *AGI* (Vol. 171, pp. 362-373).

Wawrla, L., Maghazei, O. and Netland, T., 2019. Applications of drones in warehouse operations. *Whitepaper. ETH Zurich, D-MTEC*.

Webb, J., 2020. *AI Is A Lie - Eric Jonas On AI Hype And Questions Of Ethics*. [online] O'Reilly Media. Available at: <https://www.oreilly.com/radar/ai-is-a-lie/> [Accessed 6 July 2020].

Wirth, N., 2018. Hello marketing, what can artificial intelligence help you with?. *International Journal of Market Research,* 60(5), pp.435-438.

Woodling, D., 2020. Hole up! Government urged to 'act now' over pothole-plagued roads causing serious damage to 4,000 cars each month. *The Sun*, [online] 19 July. Available at: < https://www.thesun.co.uk/uncategorized/12161891/pothole-plagued-roads damage-4000-cars//> [Accessed 19 July 2020].

Yudkowsky, E., 2008. Artificial intelligence as a positive and negative factor in global risk. *Global catastrophic risks*, 1(303), p.184.

Zainul, E. and Shankar, A. C., 2020. Malaysian economy’s supply side seen rebounding in 2021 after 2020 contraction. *The Edge Market*, [online] 6 Nov. Available at: < https://www.thesun.co.uk/uncategorized/12161891/pothole-plagued-roads damage-4000-cars//> [Accessed 25 Jan 2020].

Zhang, S., Wu, Y., Yan, H., Du, X., Zhang, K.M., Zheng, X., Fu, L. and Hao, J., 2019. Black carbon pollution for a major road in Beijing: Implications for policy interventions of the heavy-duty truck fleet. *Transportation Research Part D: Transport and Environment, 68*, pp.110-121.

Zuhra Junaida, H. and Nurul Fatimah, R., 2020. Construction Logistics Safety Measures. *International Journal of Supply Chain Management*, 9(1), pp.881-88.

APPENDICES

APPENDIX A: Questionnaires Survey Sample

THE READINESS OF ARTIFICIAL INTELLIGENCE (AI) FOR CONSTRUCTION LOGISTICS

Dear Sir / Madam,

I am Lau Sin Ying, a final year student who currently pursuing my degree in Quantity Surveying at University Tunku Abdul Rahman (UTAR). Currently, I am conducting a survey regarding to my Final Year Project entitled "TO EXAMINE THE READINESS OF ARTIFICIAL INTELLIGENCE (AI) IN CONSTRUCTION LOGISTICS".

This research aims to examine the readiness of industrial players towards the adoption of Artificial Intelligence in construction logistics with the following objectives:

i. To uncover the problems faced in current construction logistics practices.
ii. To identify the existing practice of Artificial Intelligence in construction logistics.
iii. To study the readiness of industrial players to adopt AI in the practices in construction logistics.

This questionnaire consists of FOUR (4) sections which will take approximately 5 to 10 minutes to complete. Your contribution and opinions will be greatly help to my research and all feedback provided will be kept private and confidential. It will only be used for academic purposes only for my research.

Thank you for taking the time to complete this questionnaire. If you have any queries, please do not hesitate to contact Lau Sin Ying at 018-6659117 or email to sinying980301@1utar.my.

Section A: Demographic Information

A1) Which of the following best describes your organization's industry?

- Contractor
- Subcontractor
- Supplier
- Specialist
- Logistics service providers

A2) Which of the following best describes your role?

- Assistant
- Executive
- Manager/Project Manager
- Deputy Director/ Director

A) How long is your working experience in the construction industry?

- Less than 2 years
- 3 – 5 years
- 6-10 years
- More than 10 years

Section B: Adoption of Artificial Intelligence in Construction Logistics

B1) In your perception, how relevant are the AI adoptions to the listed construction logistics activities?
[1 = Not at all, 2 = Slight, 3 = Moderately, 4 = Very, 5 = Extremely]

	1	2	3	4	5
Process of contracts and invoices					
Further planning after prediction of delay					
Monitoring health and safety of site workers					
On-site and off-site warehousing					
Planning and management of unloading and loading zones					
Delivery and traffic management					
Unloading and loading of materials					

B2) In your perception, to what extent your organizations plan to adopt AI in the following construction logistics?
[1 = Not plan at all, 2 = Expect to use in future if able, 3 = Expect to use, 4 = Expect to use in 3 years, 5 = Using now]

	1	2	3	4	5
Process of contracts and invoices					
Further planning after prediction of delay					
Monitoring health and safety of site workers					
On-site and off-site warehousing					
Planning and management of unloading and loading zones					
Delivery and traffic management					
Unloading and loading of materials					

B3) In your perception, to what extend do you agree with the following statements?
[1 = Strongly disagree, 2 = Slightly disagree, 3 = Uncertain, 4 = Slightly agree, 5 = Strongly agree]

	1	2	3	4	5
AGV is useful for repetitive transportation works in warehouse.					
AI-based drone is useful for producing a detailed map of construction sites.					
Predictive analytics is useful for reducing the uncertainty in logistics activities.					
UAV and UGV are useful for tracking the inventories.					
AI-powered jobsite camera is useful for ensuring site security, workers' safety and analysing the flow of materials on site.					
AI-back office is useful for detecting fraud by logistics service providers, classifying contractual clauses, managing and keeping all delivery information precisely.					
Autonomous truck is useful for repetitive delivery in factories, logistics centre or ports with high preciseness.					
AI developer kits is useful for making AI robotics applications becomes more easier by making existing equipment autonomous.					
Unmanned tower crane is useful to lift materials by voice recognition.					
Smart construction lift is useful to lift materials by determining running zones themselves efficiently.					

B4) In your perception, to what extent your organization plan to adopt these AI in construction logistics?
[1 = Not plan at all, 2 = Expect to use in future if able, 3 = Expect to use, 4 = Expect to use in 3 years, 5 = Using now]

	1	2	3	4	5
Automated Guided Vehicles (AGV)					
Unmanned Aerial Vehicles (UAV) and Unmanned Ground Vehicles (UGV)					
Autonomous Truck					
Unmanned Tower Crane					
Smart Construction Lift					
AI-Based Drones					
AI-powered Jobsite Cameras					
AI-Back Office					
Predictive Analytics					
AI Developer Kits					

<u>Section C: Problems in Current Construction Logistics Practice</u>

C1）In your perception, how serious is the following problems in current construction logistics practices?
[1 = Not at all, 2 = Slight, 3 = Moderately, 4 = Very, 5 = Extremely]

	1	2	3	4	5
Cost and time easily overrun due to poor logistics management, theft, misplacement of materials, materials damages and so on					
Heavy construction vehicles seriously affect people for example producing noise pollution, causing traffic jam, endangering road users and damage roads.					
Heavy construction vehicles which primarily powered by diesel fuels also cause air pollution in urban area					
Construction workers face health and safety problems which caused by the mobile plant and vehicles on site.					
Lack of collaborations among project members to manage each logistics activities.					

C2）To what extent these problems happened to the construction logistics in your current and previous project?
[1 = Never, 2 = Seldom, 3 = Sometimes, 4 = Frequently, 5 = Always]

	1	2	3	4	5
Cost Overrun					
Time Overrun					
Air Pollution caused by heavy vehicles					
Noise Pollution caused by heavy vehicles					
Roads are damaged and road users are endangered by heavy vehicles					
Construction workers' health and safety are endangered by plants and vehicles on site					
Lack off collaborations among project members					

C3) In your perception, to what extent you agree the benefits incurred to construction logistics due to the Logistics 4.0 (with aids of technology, eg: AI, BIM, IOT and so on) in construction logistics?

[1 = Strongly disagree, 2 = Slightly disagree, 3 = Uncertain, 4 = Slightly agree, 5 = Strongly agree]

	1	2	3	4	5
Improve productivity					
Save cost					
Increase revenue					
Improve efficiency and effectiveness					
Improve transparency and flexibility					
Ensure higher safety					
Environmentally friendly					

<u>Section D: Challenges of Artificial Intelligence (AI) Adoptions</u>

D1) In your perceptions, to what extent you agree the followings undermine the adoption of AI?

[1 = Strongly disagree, 2 = Slightly disagree, 3 = Uncertain, 4 = Slightly agree, 5 = Strongly agree]

	1	2	3	4	5
Algorithms aversion (which means humans tend to averse to algorithmic forecasters even they outperform a human forecaster)					
Change of working culture (human labours will be reduced and replaced by a machine)					
Lack of leadership commitment (directors and top management might resistant to change to avoid the situation cost overweight revenue)					
Lack of employees commitment (troublesome for employees in learning and practicing new skills					
Privacy concerns (which involves data persistence, data repurposing and data spillovers)					
Environmental concerns (which involves vast energy consumption for big data centres and dataset)					